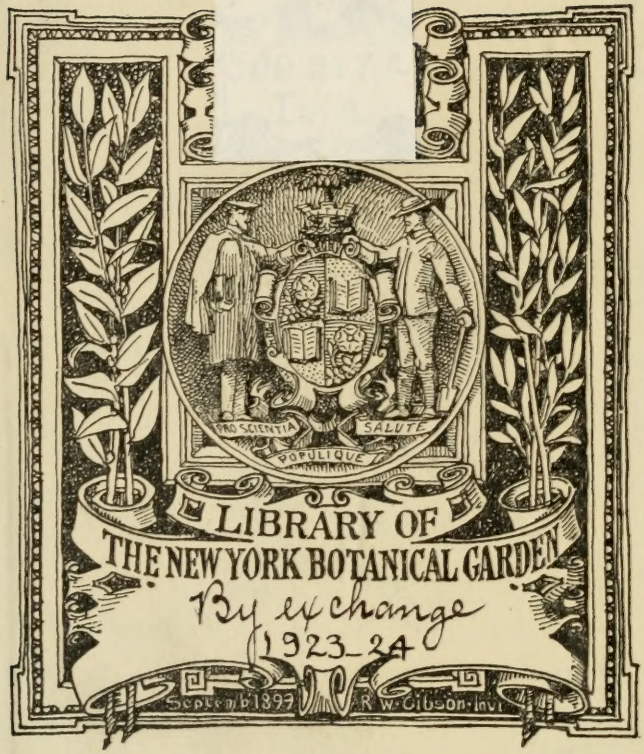
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PROCEEDINGS

OF THE

THIRTY-EIGHTH ANNUAL MEETING

OF THE

INDIANA ACADEMY OF SCIENCE

1922

PROCEEDINGS

OF THE

THIRTY-EIGHTH ANNUAL MEETING

OF THE

INDIANA ACADEMY OF SCIENCE

1922

J. J. DAVIS, EDITOR

INDIANAPOLIS:
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TABLE OF CONTENTS

	Page
Officers and Committees for 1922	6
Past Officers of the Academy	8
Minutes of the Spring Meeting	9
Winter Meeting	11
Program	11
Minutes of Business Session	16
Minutes of General Session	18
Papers—General—	
Memorial to Frank Barbour Wynn: Robert W. McBride	25
Memorial to Alexander Smith: Robert Edward Lyons	29
Memorial to Earl Jerome Grimes: Harry F. Dietz	35
Presidential Address—Some Problems of Plant Physiology: F. M. Andrews	37
Francis Galton, Life and Work: Robert Hessler	57
Life and Mind: Robert W. McBride	61
Estimating the Comparative Richness of Indiana: Stephen Sargent Visher	69
The Southern Ute Indians of Pine River Valley, Colorado: Albert B. Reagan	73
Twinkling Star: Albert B. Reagan	75
Papers on Geology, Geography and Archeology—	
History of the Lakes near Laporte, Indiana: W. M. Tucker	83
Abandoned Channels in Randolph and Delaware Counties, Indiana: Frederick J. Breeze	95
Some Contrasts between Geographic Regions in Indiana: Stephen S. Visher	99
The Paleolithic Stone Age in Indiana: S. F. Balcom	105
Recent Archeological Discoveries in Jefferson County, Indiana: Glenn Culbertson	119
Archeology in Posey and Vanderburg Counties: A. J. Bigney	121
Goniobasis livescens Menke, a Pleistocene Shell in Furnessville Blowout, Dunes of Porter County: Marcus Ward Lyon, Jr	123
A Review of the Present Knowledge of Fossil Scorpions with the Description of a new species from the Pottsville Formation of Clay County, Indiana: John Irwin Moore	125
Three New Brackish-water Pliocene Mollusca from Louisiana: Ernest Rice Smith	135
Papers on Chemistry and Physics—	
Qualitative Analysis—Tin Group: Ralph W. Hufferd	137
Qualitative Analysis—Iron Group: Ralph W. Hufferd	138
The Effect of Non-Metallic Impurities on Cementite Distribution in Steel: G. B. Wilson	141
A Study of, and a Modified Method for, Vogel's Reaction for Cobalt: F. J. Allen and A. R. Middleton	147

NOV 13 1923

Papers on Chemistry and Physics—Continued— PAGE

Thiocyanotocobaltous Acid and its Alkali Salts: F. J. Allen and A. R. Middleton ... 153
Evaporation of Solutions and Liquids in Burettes: M. G. Mellon ... 159
The use of Solutions of Inorganic Salts as Permanent Color Standards: M. G. Mellon ... 164
An Improved Murexide Test for Teaching Purposes: Samuel E. Earp 173
Fog Formation in Air which has passed through a Silent Discharge: F. O. Anderegg and K. B. McEachron ... 175
An Oscillographic Study of an Induction Coil with High Frequency Load: F. O. Anderegg and K. B. McEachron ... 178
A Type of Silent Discharge involving Catalysis: F. O. Anderegg and E. H. Bowers ... 181
A Further Study of Pressure Reversals in the Corona Discharge: F. O. Anderegg ... 187
Improved Designs of Sound Condensers: Arthur L. Foley ... 191
Locomotive Whistle Experiments: Arthur L. Foley ... 193
A Method of Measuring the Amplification of two or more Stage Amplifiers: R. R. Ramsey ... 195
A Method of Securing Accurate High Frequency Standard: R. R. Ramsey ... 197
An Investigation of the Foley Telephone Mouthpiece: James E. Brock 199

Papers on Biology—

The Occurrence of Secondary Parasitism in the Frog: George Zebrowski ... 205
Notes on the Mammals of the Dune Region of Porter County, Indiana: Marcus Ward Lyon, Jr. ... 209
Reactions to Light and Photoreceptors of *Lumbricus terrestris*: Walter N. Hess ... 223
Chromosomal Variations in the Earwig, *Anisolabris annuleipes* Lucas: W. P. Morgan ... 225
A Hygrothermograph Puzzle: W. H. Larrimer ... 231
Nagana (*Trypanosoma brucei*): The Course of the Disease in Laboratory Animals when injected with Cultures grown *in vivo* and *in vitro:* Charles A. Behrens ... 233
The Use of Clark and Lubs Indicators for the Detection of Acid Production by the Colon-Typhoid Group: P. A. Tetrault ... 247
Soil Bacterial Types and Green Manuring: I. L. Baldwin and A. J. Smith ... 253
A Simple Method of determining the Thermal Death-point: James B. Kendrick and Max W. Gardner ... 257
Further notes on the Unusual Stipules of *Acer nigrum* Michx: Flora Anderson ... 259
Unusual Branching in Cladophora: Flora Anderson ... 261
Plants New to Indiana, XI.: C. C. Deam ... 263
The Effect of Pressure on Seedlings: F. M. Andrews ... 265
Chloroplasts of *Martynia fragrans:* F. M. Andrews ... 267
Quantitative Estimation of Aeration in Leaves: F. M. Andrews ... 268
An Unusual Iris: F. M. Andrews ... 270
Second Blooming of Snowball Bush in the Same Year: F. M. Andrews 270

Papers on Biology—Continued— PAGE
The Convolvulaceae of Indiana: Truman G. Yuncker ... 273
Plants of White County, V.: Louis F. Heimlich ... 281
The Ustilaginales of Indiana, III.: H. S. Jackson ... 291
Recent Indiana Weeds: Albert A. Hansen ... 293
Wild Corn, a Serious Weed in Indiana: Albert A. Hansen ... 295
Embryonic Selections in Certain Nut Bearing Pines: David M. Mottier ... 297
Phytophthora Rot of Tomato, Eggplant, and Pepper: James B. Kendrick ... 299
Differences in the Susceptibility of Clover to Powdery Mildew: E. B. Mains ... 307
The Present Status of the Hot Water Treatment in Indiana: C. T. Gregory ... 315
Onion Smut in Indiana: C. T. Gregory ... 318
The Making of Genera in Fungi: J. M. Van Hook ... 321
Notes on Microtechnique, II.: M. S. Markle ... 323
Constitution and By-Laws ... 325
List of Members ... 329

OFFICERS AND COMMITTEES FOR 1922.

President, F. M. ANDREWS, Indiana University, Bloomington.
Vice-President, C. A. BEHRENS, Purdue University, Lafayette.
Secretary, WALTER N. HESS, DePauw University, Greencastle.
Assistant Secretary, HARRY F. DIETZ, State Conservation Commission, Indianapolis.
Press Secretary, FRANK B. WADE, Shortridge High School, Indianapolis.
Treasurer, WILLIAM M. BLANCHARD, DePauw University, Greencastle.
Editor, 1922 Proceedings, J. J. DAVIS, Purdue University, Lafayette.

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(Officers and Past-Presidents)

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BEHRENS, C. A.	DAVIS, J. J.	MOTTIER, DAVID M.
BIGNEY, A. J.	DIETZ, H. F.	MENDENHALL, T. C.
BLANCHARD, W. M.	DRYER, CHAS. R.	NAYLOR, JOSEPH P.
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Archeological Survey

Frank B. Wynn,* Indianapolis.
R. W. McBride, 1239 State Life Building, Indianapolis.
W. N. Logan, Indiana University, Bloomington.
Allen D. Hole, Earlham College, Richmond.
Stanley Coulter, Purdue University, Lafayette.
Chas. Stoltz, 311 W. Jefferson Blvd., South Bend.
A. J. Bigney, Evansville College, Evansville.
Glenn Culbertson, Hanover College, Hanover.
W. A. McBeth, State Normal, Terre Haute.
S. F. Balcom, 3634 Birchwood Ave., Indianapolis.

Auditing.

E. B. Williamson, Bluffton.
Rollo R. Ramsey, Indiana University, Bloomington.

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H. S. Jackson, Purdue Agricultural Experiment Station, Lafayette.
Richard Lieber, State Conservation Commission, Indianapolis.
J. J. Davis, Purdue University, Lafayette.
Will Scott, Indiana University, Bloomington.

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Walter N. Hess, DePauw University, Greencastle.
Wm. M. Blanchard, DePauw University, Greencastle.

Membership.

Harry F. Dietz, State Conservation Commission, Indianapolis.
W. A. Cogshall, Indiana University, Bloomington.
Ralph H. Carr, Purdue University, Lafayette.
M. L. Weems, Valparaiso University, Valparaiso.

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C. C. Deam, Bluffton.
H. L. Bruner, Butler College, Indianapolis.

Program.

R. C. Friesner, Butler College, Indianapolis.
H. L. Bruner, Butler College, Indianapolis.
W. M. Blanchard, DePauw University, Greencastle.

Publication of Proceedings.

F. Payne, Indiana University, Bloomington.
O. B. Christy, State Normal, Muncie.
Harry F. Dietz, State Conservation Commission, Indianapolis.

Relation of Academy to the State.

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Glenn Culbertson, Hanover College, Hanover.
John S. Wright, Eli Lilly and Co., Indianapolis.
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Glenn Culbertson, Hanover College, Hanover.
A. L. Foley, Indiana University, Bloomington.
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* Died July 27, 1922.

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1915–1916	A. J. Bigney	Howard E. Enders	E. B. Williamson	F. B. Wade	Wm. M. Blanchard.
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1920–1921	Howard E. Enders	Walter N. Hess	Harry F. Dietz	F. B. Wade	Wm. M. Blanchard
1921–1922	F. M. Andrews	Walter N. Hess	Harry F. Dietz	F. B. Wade	Wm. M. Blanchard.
1922–1923	Charles A. Behrens	Walter N. Hess	Flora C. Anderson	Harry F. Dietz	Wm. M. Blanchard.

*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic.

MINUTES OF THE SPRING MEETING.

French Lick, Indiana.

The Spring Meeting of the Academy afforded its members and friends an opportunity to study the remarkable Lost River district of Orange County. The underlying rocks of this region are limestone, and due to spectacular stream trenching, are largely responsible for the hills, valleys and caves of the present time.

In addition to exploring the Lost River basin, the party visited the springs and rock formations of the French Lick valley, including Cross Cave. Prof. C. A. Malott, together with other members of the Academy who were familiar with the region, acted as guides.

The meeting was planned to cover three days, Thursday, Friday and Saturday, May 11, 12 and 13, 1922.

Thirty-eight members and eleven guests were in attendance at the meetings and on the trips.

Thursday, May 11.

Members of the Academy and their friends met at the Windsor Hotel, French Lick. At 2:00 p.m. the party started on a field trip through the French Lick valley for the purpose of visiting the numerous mineral springs, rock formations and hills which have been left as a result of valley erosion.

After dinner at the Windsor Hotel, the members and their guests assembled at the Christian Church for a brief business meeting. Following the business meeting, Prof. C. A. Malott, of Indiana University, gave a very interesting and instructive lecture on the geology of Lost River. By means of clear descriptions and excellent charts Prof. Malott also discussed the geology of the country that was to be visited on Friday.

Friday, May 12.

The party left the Windsor Hotel at 8:00 a.m. for Stamper's Creek in order to study this creek at the point where it becomes subterranean.

Lost River was next studied. It was first viewed as a rather large stream flowing over a rather flat limestone country. A few miles below, it was found to disappear by means of small sinks in the river bottom. The next stop was made at the first storm swallow-hole which, under moderate rainfall, takes care of all the water that does not disappear farther up the stream. The second storm-hole, which receives the overflow during severe rains, was also visited.

The party arrived at Wesley Chapel at noon, where a sumptuous chicken dinner was served. The early part of the afternoon was spent in Wesley Chapel Gulf, which is a collapsed sink of the Lost River subterranean channel.

On the way back to French Lick the party stopped at Orangeville, where Lost River once more rises to the surface.

After supper the evening was spent at the Windsor Hotel in making and renewing acquaintances.

Saturday, May 13.

Before starting home several of the company visited the "Gorge" about two miles southeast of French Lick for the purpose of studying the geological formations.

Those of the party who went by automobile to Bloomington greatly enjoyed a visit to the caves at Mitchell with Prof. and Mrs. Eigenmann.

Business Session.

French Lick, Indiana, May 11, 1922.

The members of the Academy assembled in the Christian Church, where the meeting was called to order at 7:30 p. m. by President F. M. Andrews.

The request of Prof. A. Richards, formerly of Wabash College, to be placed on the non-resident list was declined but it was voted that since he and Mrs. Richards did not desire to each carry active membership, that their names be made to read Dr. and Mrs. A. Richards and be considered as one membership.

A communication from Prof. Ehlers of the Michigan Academy was read. He extended an invitation to the Geological Section of the Indiana Academy to join them in their spring meeting.

Prof. Cogshall of the Membership Committee proposed the names of the following persons who were duly elected to membership:

Allee, W. N., 221 E. Fourth St., Bloomington.

Barnett, Horace L., Department of Geology, Indiana University, Bloomington.

Dean, Miss Grace, French Lick.

Pearson, Nathan E., Department of Zoology, Indiana University, Bloomington.

Senour, Frank C., 323 N. Grant St., Bloomington.

A letter was read from Dr. H. W. Wiley expressing his regret at not being able to attend the Spring Meeting.

President Andrews read a letter from Mrs. Frank Sheehan regarding the Dunes Summer Camp. He stated that several members of the University of Chicago staff were helping to promote this camp, which indicated that it was for educational and scientific purposes.

The following suggestions were made as to the possible place of holding the meeting next year: Dunes, Culver Military Academy and vicinity, Anderson, Richmond, Madison, lakes region of Steuben County. It was suggested that the Michigan Academy might wish to join us in a meeting if held in the lakes region.

Adjourned at 8:10 p. m.

F. M. Andrews,
President.

Walter N. Hess,
Secretary.

WINTER MEETING.

PROGRAM OF THE THIRTY-EIGHTH ANNUAL MEETING

OF

THE INDIANA ACADEMY OF SCIENCE

HELD AT

LINCOLN HOTEL, INDIANAPOLIS.

December 7 and 8, 1922.

PROGRAM COMMITTEE.

R. C. FRIESNER. H. L. BRUNER.

W. M. BLANCHARD.

DECEMBER 7, 1922.

8:00 p. m. Executive Committee Meeting.
Reports of Committees.

DECEMBER 8, 1922.

9:00- 9:30 a. m. General Business Meeting.

9:30-12:00 m. General Session.

Estimating the Comparative Richness of Indiana. Stephen S. Visher, Indiana University.

*A Photographic Study of Architectural Acoustics. (Illustrated.) Arthur L. Foley, Indiana University. (Published in The American Architect and Architectural Review, November 8, 1922.)

Francis Galton, Life and Work. Robert Hessler, Indianapolis.

The Paleolithic Stone Age in Indiana. (Illustrated.) S. Frank Balcom, Indianapolis.

Recent Archeological Discoveries in Jefferson County, Indiana. Glenn Culbertson, Hanover College.

*The Smog Problem. Robert Hessler, Indianapolis.

Life and Mind. Robert W. McBride, Indianapolis.

*The Scientific Work of the Conservation Commission. (By title.) Stanley Coulter, Purdue University.

The Southern Ute Indians of Pine River Valley, Colorado. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

*Indian Funerals. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

Twinkling Star. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

Frank Barbour Wynn: In Memoriam. Robert W. McBride, Indianapolis.

Alexander Smith: In Memoriam. R. E. Lyons, Indiana University.

Earl Jerome Grimes: In Memoriam. Harry F. Dietz, State Conservation Commission.

Address of the Retiring President: Some Problems in Plant Physiology. Frank M. Andrews, Indiana University.

1:30- 2:00 p. m. General Business Meeting.

2:00- 5:30 p. m. Sectional Meetings.

* Papers starred (*) not published in this Proceedings.

GEOLOGY AND GEOGRAPHY.

History of the Lakes near Laporte, Indiana. William Motier Tucker, Indiana University.

*Mineral Resources of Indiana. W. N. Logan, Indiana University.

Goniobasis livescens Menke, a Pleistocene Shell in Furnessville Blowout, Dunes of Porter County. (Illustrated.) Marcus W. Lyon, Jr., South Bend.

*Valley-Heads and Sheet-Wash Erosion. Clyde A. Malott, Indiana University.

*The Role of Sheet-Wash in Erosion. Clyde A. Malott, Indiana University.

A Review of the Present Knowledge of Fossil Scorpions with the Description of a new species from the Pottsville Formation of Clay County, Indiana. (By title.) John Irvin Moore, Owensville.

Some Contrasts between Geographic Regions in Indiana. Stephen S. Visher, Indiana University.

Abandoned Channels in Randolph and Delaware Counties, Indiana. Frederick J. Breeze, Indiana State Normal School, Eastern Division.

*The Muncie Esker. Frederick J. Breeze, Indiana State Normal School, Eastern Division.

*The Entrenched Meanders and Associated Terraces in the Muscatatuck River, near Vernon, Indiana. Burton J. Malott, Technical High School, Indianapolis.

†A new Pleistocene Gastropod from Maryland. (By title.) Ernest Rice Smith, DePauw University.

Archeology in Posey and Vanderburg Counties, Indiana. Andrew J. Bigney, Evansville College.

CHEMISTRY AND PHYSICS.

Chemistry.

Qualitative Analysis—Tin Group. Ralph W. Hufferd, DePauw University.

Qualitative Analysis—Iron Group. Ralph W. Hufferd, DePauw University.

*The Normal System in Quantitative Analysis. E. G. Mahin, Purdue University.

The Effect of Non-Metallic Impurities on Cementite Distribution in Steel. (Illustrated.) G. B. Wilson, Purdue University.

*Some Toxic Soils of Indiana. (Illustrated.) R. H. Carr, Purdue University. (Published under the title "Manganese, Aluminum, and Iron Ratio as Related to Soil Toxicity," in Journal of Industrial and Chemical Engineering, June, 1923.)

A Study of, and a Modified Method for, Vogel's Reaction for Cobalt. F. J. Allen and A. R. Middleton, Purdue University.

Thiocyanotocobaltous Acid and Its Alkali Salts. F. J. Allen and A. R. Middleton, Purdue University.

* Papers starred (*) not published in this proceedings.

† Another title substituted in this Proceedings.

Evaporation of Solutions in Burettes. M. G. Mellon, Purdue University.

The Use of Solutions of Inorganic Salts as Permanent Color Standards, M. G. Mellon, Purdue University.

An Improved Murexide Test for Teaching Purposes. Samuel E. Earp, Indianapolis.

Fog Formation in Air Which Has Passed Through a Silent Discharge. (Illustrated). F. O. Anderegg and K. B. McEachron, Purdue University.

A Type of Silent Discharge Involving Catalysis. (Illustrated.) F. O. Anderegg and E. H. Bowers, Purdue University.

A Further Study of Pressure Reversals in the Corona Discharge. (Illustrated.) F. O. Anderegg, Purdue University.

*The Peculiar Properties of Water in light of its Molecular Structure. (Illustrated.) F. O. Anderegg, Purdue University.

Physics.

*Some Untenable Acoustic Theories. Arthur L. Foley, Indiana University. (Published under title "A Photographic Study of Sound Pulses between Curved Walls and Sound Amplification by Horns," in Physical Review, S.S., vol. 20, no. 6, December, 1922.)

Improved Designs of Sound Condensers. (Illustrated.) Arthur L. Foley, Indiana University.

Locomotive Whistle Experiments. (Illustrated). Arthur L. Foley, Indiana University.

*Energy Losses in Commercial Hammers. (Illustrated.) Edwin Morrison, Michigan Agricultural College.

*Scattering of Light by Small Particles. (Illustrated.) Edwin Morrison, Michigan Agricultural College.

*Spectrum of Phosphorescent Mercury. (Illustrated.) E. K. Chapman, Wabash College.

A Method of Measuring the Amplification of Two or More Stage Amplifiers. (Illustrated.) R. R. Ramsey, Indiana University.

A Method of Securing Accurate High Frequency Standard. R. R. Ramsey, Indiana University.

An Oscillographic Study of an Induction Coil with High Frequency Load. F. O. Anderegg and K. B. McEachron, Purdue University.

An Investigation of the Foley Telephone Mouthpiece. (Illustrated.) James E. Brock, Sweetser.

*Diffraction of Light through Circular Openings. (Illustrated.) Mason E. Hufford, Indiana University.

BIOLOGICAL SCIENCES.

Zoology.

*Some Genes Modifying Crossing-Over. F. Payne, Indiana University.

The Occurrence of Secondary Parasitism in the Frog. (By title.) George Zebrowski, Purdue University.

* Papers starred (*) not published in this proceedings.

*Relation of Insects to Human Life and to the other Sciences. John J. Davis, Purdue University.

*Content of First Course in Zoölogy. R. A. Gantz, Indiana State Normal School, Eastern Division.

Notes on Mammals of the Dune Region of Porter County, Indiana. (Illustrated.) Marcus W. Lyon, Jr., South Bend.

*Notes on the Termites of Indiana. (Illustrated.) Harry F. Dietz, Indianapolis.

*Complement-deficient Guinea-pig Serum. (By title.) Roscoe R. Hyde, Johns Hopkins University. (To be published in American Journal of Hygiene, 1923.)

Reactions to Light and Photoreceptors of *Lumbricus terrestris*. Walter N. Hess, DePauw University.

Chromosomal Variations in the Earwig, *Anisolabris annuleipes* Lucas. W. P. Morgan, Indiana Central College.

A Hygrothermograph Puzzle. W. H. Larrimer, U.S. Entomological Laboratory, West Lafayette.

*A Study of the Virginia Opossum. W. H. Sheak, Ijamsville.

Bacteriology.

Nagana (*Trypanosoma brucei*): The Course of the Disease in Laboratory Animals when Injected with Cultures Grown *in vivo* and *in vitro*. Charles A. Behrens, Purdue University.

The Use of Clark and Lubs Indicators for the Detection of Acid Production by Colon-Typhoid Group. P. A. Tetrault, Purdue University.

Soil Bacterial Types and Green Manuring. I. L. Baldwin, Purdue University.

A Simple Method of Determining the Thermal Death-point. James B. Kendrick and Max W. Gardner, Purdue Agricultural Experiment Station.

Botany.

Further Notes on the Unusual Stipules of *Acer nigrum* Michx. Flora Anderson, Indiana University.

†Unusual Branching in Cladophora. Flora Anderson, Indiana University.

Plants New to Indiana. XI. C. C. Deam, Bluffton.

*Attack of Fungi on the Lids of Water Culture Jars. F. M. Andrews, Indiana University.

The Effect of Pressure on Seedlings. F. M. Andrews, Indiana University.

The Convolvulaceae of Indiana. Truman G. Yuncker, DePauw University.

Recent Indiana Weeds. Albert A. Hansen, Purdue Agricultural Experiment Station.

Wild Corn as a Weed Problem in Indiana. Albert A. Hansen, Purdue Agricultural Experiment Station.

* Papers starred (*) not published in this proceedings.
† Another title substituted in this Proceedings.

*List of Indiana Plants, Chiefly from Putnam County. Collected 1911-1915 by Earl Jerome Grimes. (By title.) Mrs. Eileen W. Grimes, University of Michigan.

*Polyembryony in Species of Osmunda and Dryopteris. David M. Mottier, Indiana University.

Embryonic Selection in Certain Nut Bearing Pines. David M. Mottier, Indiana University.

Phytophthora Rot of Tomato, Eggplant and Pepper. James B. Kendrick, Purdue Agricultural Experiment Station.

Differences in the Susceptibility of Clover to Powdery Mildew. (Illustrated.) E. B. Mains, Purdue Agricultural Experiment Station.

Notes on Microtechnique. II. M. S. Markle, Earlham College.

Chloroplasts of *Martynia fragrans*. F. M. Andrews, Indiana University.

Quantitative Estimation of Aeration in Leaves. F. M. Andrews, Indiana University.

*Indiana Plant Diseases, 1922. (Illustrated.) Max W. Gardner, Purdue Agricultural Experiment Station.

†Indiana Fungi. VII. J. M. Van Hook, Indiana University.

*Relation of Barberry to Stem Rust of Wheat: Results of Indiana Survey. (Illustrated.) K. E. Beeson (introduced by H. S. Jackson), Purdue Agricultural Experiment Station.

An Unusual Iris. F. M. Andrews, Indiana University.

Second Blooming of a Snowball Bush in the Same Year. F. M. Andrews, Indiana University.

The Present Status of the Hot Water Treatment of Wheat in Indiana. Charles Gregory, Purdue Agricultural Experiment Station.

Onion Smut in Indiana. Charles Gregory, Purdue Agricultural Experiment Station.

Plants of White County. V. Louis F. Heimlich, Purdue University.

*The Microscopy of Flour. (By title.) Harold E. Turley, American Institute of Baking, Chicago, Ill. (Published in Baking Technology, November 15, 1922.)

6:00- 8:00 p. m. Annual Academy Dinner.

8:00-10:00 p. m. General Session.

*The Fundamental Principles of Radio Transmission and Reception. (Illustrated.) R. R. Ramsey, Indiana University.

*The Scientific Propagation of Black Bass in Ponds as Conducted at the Riverside Station in Indianapolis. (Two reels motion pictures.) G. M. Mannfeld, State Conservation Commission.

*The Artificial Propagation of Pike-Perch. (One reel motion pictures.) G. M. Mannfeld, State Conservation Commission.

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* Papers starred (*) not published in this proceedings.

† Another title substituted in this Proceedings.

MINUTES OF BUSINESS SESSION.

LINCOLN HOTEL, INDIANAPOLIS.

MEETING OF THE EXECUTIVE COMMITTEE.

December 7, 1922.

The Executive Committee was called to order at 8:15 p. m. in Parlor E, by President F. M. Andrews. The following members were present: F. M. Andrews, C. A. Behrens, W. M. Blanchard, F. J. Breeze, W. A. Cogshall, Stanley Coulter, Glenn Culbertson, H. F. Dietz, H. E. Enders, A. L. Foley, R. C. Friesner, W. N. Hess, R. W. McBride, D. M. Mottier, J. P. Naylor, F. Payne, E. B. Williamson, J. S. Wright.

The minutes of the last meeting of the Executive Committee were read and approved.

Committee reports were considered as follows:

Committee on Program.

Chairman R. C. Friesner presented the printed program of 95 titles to be read at the general sessions tomorrow. He called attention to the crowded condition of the program and that each branch of science had sufficient number of papers for a section of its own. A letter from the Ohio Academy reiterated its desire to hold a joint meeting with the Indiana Academy in the near future. Professor Friesner stated that there had been some criticism because the programs were mailed out early. He explained that the printed programs contained all titles received up to November 9 and that they were mailed out on November 17. He further stated that the supplementary list contained all titles received up to and including December 7.

Professor Friesner asked for an expression from the Academy concerning the advisability of having the meeting next year at one of the educational institutions. After some discussion Judge McBride moved that the Executive Committee select the place of meeting instead of the Program Committee. Passed.

Committee on Membership.

Mr. Dietz reported 51 new names to be presented at the meeting tomorrow. He spoke of the fine co-operation received from all who were asked to aid in securing new members.

Committee on Biological Survey.

No report.

Committee on Distribution of Proceedings.

Professor Hess reported that the 1921 Proceedings were mailed out in August. He requested help in keeping the mailing list correct and asked all members who did not receive their copy of the Proceedings to advise him.

Committee on Relation of the Academy to the State.

Judge Robert W. McBride reported that the present cuts in appropriations would not affect the funds of the Academy.

Report of the Treasurer.

Balance on hand December 1, 1921	$299 16
Dues collected during the year	385 00
Total	$684 16
Total expenditures	351 59
Balance in treasury December 1, 1922	$332 57

(The treasurer's account does not include the funds appropriated by the State for the publication of the Proceedings. Editor.)

Committee on Auditing.

Mr. E. B. Williamson reported on the accuracy of the treasurer's report. A motion authorizing the transfer of $100.00 from the treasury to the trustees of the Research Endowment Fund was introduced by Professor Blanchard. Passed. This motion was later rescinded.

Committee on Publication of Proceedings.

Chairman F. Payne stated that it had been demonstrated as possible to secure prompt publication of the Proceedings. He stated that we still owed the Fort Wayne Printing Company about $150.00 on an old account. After some discussion it was moved and passed that this sum be paid from the surplus funds of the State which were left from the publication of the last Proceedings. This motion was later rescinded.

Advisory Council.

Chairman John S. Wright suggested we pay the account owing the Fort Wayne Printing Company from the funds of our own treasury. It was moved by Judge McBride that we reconsider the motion to transfer $100.00 to the trustees of the Endowment Fund, and pay the Fort Wayne Printing Company account from the treasury of the Academy. On motion the money was returned to the treasury and the Fort Wayne Printing Company bill ordered paid.

Committee on Research.

Professor J. P. Naylor announced that the Committee on Research was appointed without duties. In explanation Mr. Wright stated that the committee would probably be inactive until sufficient funds were available for research work.

Committee on Academy Foundation.

No report.

Committee on Archeological Survey.

No report.

Committee on Indexing Proceedings.

Mr. Dietz stated that there was not sufficient money at the disposal of the State Library to do this work. He suggested that the work be divided up into its natural divisions of Botany, Zoölogy, Chemistry, etc., and assigned to individuals. It was moved by Dr. Stanley Coulter that this plan be followed provided that capable men can be found who will undertake the work. Motion passed.

General Business.

Dr. A. L. Foley called attention of the Academy to the fact that, if we are to do anything about choosing a place for our meetings next year, it must be done tonight. After brief discussion it was moved by Judge McBride and passed that the incoming President, Secretary, and Treasurer be authorized to choose the place for our next winter meeting.

Professor Glenn Culbertson invited the Academy to Hanover, but stated that he thought the first meeting away from Indianapolis might better be held at some more centrally located point.

President Andrews brought up the question of an Academy seal. Mr. Wright advised the purchase of a seal and suggested the use of membership certificates. After some discussion it was moved that a committee, with power to act, be appointed to consider the purchase of a seal and the adoption of membership certificates. Passed. The following committee was appointed: Dr. Stanley Coulter, Dr. A. L. Foley, Mr. John S. Wright.

Adjourned 9:45 p. m.

MINUTES OF GENERAL SESSION.

9:00 a. m., December 9, 1922.

BUSINESS SESSION.

The session was called to order by President Andrews. The minutes of the Executive Committee were read and approved.

The Membership Committee proposed the following named persons for membership: On motion they were duly elected.

Auble, Robert N., 409 Wolcott St., Indianapolis.
Beecher, Alva, Crawfordsville, Ind.
Beeson, K. E., 427 State St., West Lafayette.
Bell, Alva Marie, 511 Smith Ave., Bloomington.
Berg, George F. Jr., 3518 Balsam Ave., Indianapolis.
Bolen, Homer R., 314 S. Grant St., Bloomington.
Book, William F., 516 N. Fess Ave., Bloomington.
Boots, Edwin B., 125 N. 6th St., W. Terre Haute.
Brock, James E., Sweetser, Ind.
Brosey, Charles L., 766 West Drive, Woodruff Place, Indianapolis.
Bushnell, T. M., Agr. Expt. Sta., West Lafayette.
Chitty, Ethel, Indiana State Normal, Muncie.
Clay, Mrs. Celia, 320 N. State St. Kendallville.
Cox, C. F., 364 N. Audubon Ave., Indianapolis.
Davis, Charles, 217 Sylvia St., West Lafayette.
Doan, Richard L., 802 E. Third St., Bloomington.
Donaghy, Frederick, Indiana State Normal, Terre Haute.
Dugan, Elizabeth, 717 N. Tremont St., Indianapolis.
Eaton, Dunwald L., Indiana Central College, Indianapolis.

Esarey, Ralph E., 924 Atwater St., Bloomington.
Gregory, Charles T., 1022 First St., W. Lafayette.
Hills, Donald H., 2127 Talbott St., Indianapolis.
Hoffer, George N., 434 Littleton St., W. Lafayette.
Hoffman, A. C., 920 East Drive, Woodruff Place, Indianapolis.
Kennedy, Clarence H., Ohio State Univ., Dept. of Zoöl., Columbus, O.
Kiester, Jackson A., 300 S. Green St., Crawfordsville.
Klipinger, Walter C., 2234 Park Ave., Indianapolis.
Knecht, Christian, 207 N. Dunn St., Bloomington.
Koehring, Vera, Butler College, Indianapolis.
Kurtz, J. M., Goshen College, Goshen.
Lanham, Bess, 610 E. Wabash Ave., Crawfordsville.
Lyon, Marcus Ward, Jr., 214 LaPorte Ave., South Bend.
McDonald, Clinton C., 415 S. Dunn St., Bloomington.
Madenwald, Frederick A., 621 E. 10th St., Bloomington.
Malott, Ruth Boyd, Butler Ave., Indianapolis.
Mannfeld, George N., 1235 Central Ave., Indianapolis.
Martin, Essie S., 134 N. Drexel St., Indianapolis.
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis.
Michael, Lyle Jordan, Indiana Central College, Indianapolis..
Montgomery, Basil E., Poseyville Ind.
Moore, John Irwin, Owensville.
Moorhead, John G., 124 DeHart St., W. Lafayette.
Mullendore, Naomi, Franklin.
Noble, Willis Bernard, Box 95, W. Lafayette.
Osbun, Clifford Leroy, 201 Russel St., W. Lafayette.
Payne, Mary, South Downey Ave., Indianapolis.
Pitkin, Edward M., 519 N. College St., Bloomington.
Protchard, R. V., Butler College, Indianapolis.
Roberts, Harry John, Route A, Lafayette.
Robertson, Ray B., 702 Evergreen St., W. Lafayette.
Smith, Lee T., R. F. D. No. 7, Bloomington.
Stirrett, George M., 521 State St., W. Lafayette.
Strickler, Alvin, Evansville College, Evansville.
Tasker, Roy C., 612 Anderson St., Greencastle.
Taylor, George O., 502 S. Sluss Ave., Bloomington.
Teeters, Charles E., 346 N. Audubon Ave., Indianapolis.
Ward, Mary Mallory, 405 E. William St., Kendallville.
Wilson, E. R., 2830 E. Vermont St., Indianapolis.
Young, Herman, 602 N. College St., Bloomington.
Zierer, Clifford M., Geography Dept., Indiana University, Bloomington.

Mr. Demarchus Brown, State Librarian, announced that there were, in the State Library, about 5,500 separate items belonging to the Academy. He stated that the library was behind in binding and that many of the foreign exchanges were only beginning to come in.

Mr. Brown called the attention of the Academy to the fact that the general public did not use the exchanges of the Academy as it is a rule of the Academy that such publications cannot be loaned except

to Academy members. After brief discussion Professor Cogshall moved, and it was passed, that the loaning of the exchanges of the Academy be left to the discretion of the State Librarian.

Mr. Brown stated, in conclusion, that the State Library was very seriously in need of more funds, and he urged the members to advise their legislators of the library needs.

Mr. Butler expressed the appreciation of the Academy for the work of Mr. Brown and his associates, and strongly urged the co-operation of each member in securing, through legislation, more funds for the use of the State Library.

Professor Enders, as chairman of the Committee on Nominations, recommended the election of the following to fellowship. Adopted: Ralph H. Carr, Harry F. Dietz, Edward G. Mahin, Paul Weatherwax.

Chairman Enders, also announced the following nominations for officers for 1923:

President.....C. A. Behrens, Lafayette
Vice-president.....F. Payne, Bloomington
Secretary.....W. N. Hess, Greencastle
Assistant Secretary.....Flora Anderson, Bloomington
Treasurer.....W. M. Blanchard, Greencastle
Editor.....J. J. Davis, Lafayette
Press Secretary.....H. F. Dietz, Indianapolis

On motion, the above named officers were elected.

Professor Enders requested that the list of the former officers of the Academy be printed each year in the Proceedings.

It was moved that the secretary be instructed to write a letter expressing our appreciation to the management of the Lincoln Hotel for the courtesies shown. Motion passed.

Professor W. M. Blanchard, in behalf of the science departments of DePauw University, invited the Academy to hold its next winter meeting at Greencastle. It was moved by Dr. Stanley Coulter that this invitation be accepted. Motion carried.

Professor J. P. Naylor introduced the following resolution which was acted upon favorably: Resolved, "That hereafter it be the sense of the Academy that no member shall occupy more than ten minutes in the presentation of a paper or abstract, except that the president's address may occupy thirty minutes. The president, or person appointed by him, shall notify the speaker when he has exhausted the time, and he can continue only by vote of the assembly to extend the time."

Dr. W. N. Logan reported for the Archeological Survey that work was being continued on the county maps, which were for the purpose of indexing archeological material.

Adjourned for sectional meetings at 2:15 p. m.

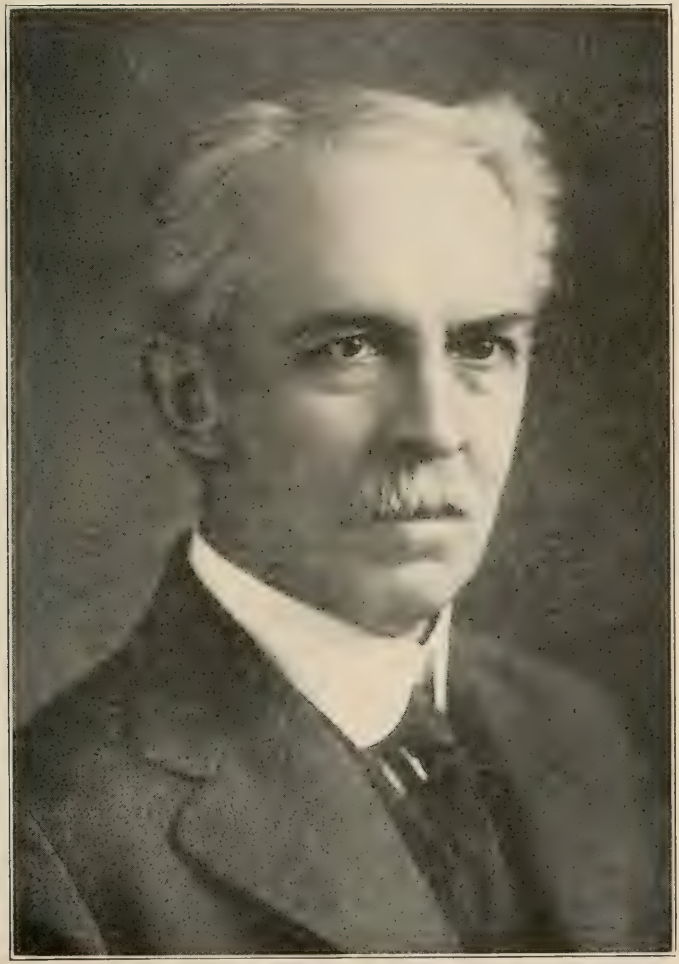
Sixty-one members and guests participated in the dinner at 6:00 p. m. At the close of the dinner the members of the Academy and their friends assembled in the Travertine room for the evening program.

The evening program included an illustrated lecture by Professor R. R. Ramsey of Indiana University, on "The Fundamental Principles of Radio Transmission and Reception". This was followed by several motion pictures, presented by Mr. G. M. Mannfeld, on the propagation of black bass and pike-perch.

At 10:30 p. m. the 38th annual meeting of the Indiana Academy of Science closed.

F. M. ANDREWS,
President.

WALTER N. HESS,
Secretary.



Frank Barbour Wynn
1860-1922

FRANK BARBOUR WYNN.

Brookville, Indiana.
May 28, 1860.

Mt. Siyeh, Montana.
July 27, 1922.

Since the last meeting of the Academy we have lost one of our most useful and most distinguished members, in the passing of Dr. Frank Barbour Wynn. He became a member of the Academy at the annual meeting in 1916, and while he contributed few papers he was prompt in his attendance and helpful and practical in his suggestions. His smiling countenance and his cheerful voice will be sorely missed by all. In his varied activities he represented the highest type of American manhood.

Frank Barbour Wynn was a native of Indiana, his birthplace, Brookville, Franklin County, Indiana, the same as that of the Indiana Academy of Science. He was born May 28, 1860. He graduated at DePauw University in 1883, with the degree of A. B. This institution, in 1886, granted him the degree of Master of Arts, and in 1922, just a month prior to his death, they conferred upon him the honorary degree of Doctor of Science. In 1885 he was graduated from the Miami Medical College, at Cincinnati, Ohio, with the degree of M. D.

He was assistant physician in the Ohio Insane Asylum, at Dayton, Ohio, from 1886 to 1888, and in 1891 he was on the medical staff of the Northern Indiana Hospital for the Insane, at Logansport. In the years 1892 and 1893 he studied in the hospitals and other institutions of New York, London, Paris, Berlin, and Vienna, and then located for the practice of his profession in Indianapolis. Since that time his activities have been so varied and of such value that no history of Indiana, covering the period from 1900 to the date of his death, can be fully and truthfully written without frequent mention of them. He was the president of the State Historical Commission, and bore a leading part in the centennial celebration of Indiana's admission to statehood. He was a valued and useful member of the Indiana Historical Society, Indianapolis Chamber of Commerce, and was chairman of the State Park Board. He was a vice-president of the American Medical Association in 1921, president of the Indiana Medical Association in 1914 and 1915, president of the Mississippi Valley Medical Association in 1920, and a fellow of the American College of Physicians. He was held in highest esteem by all his confreres. He was president of the recently organized Lincoln Memorial Association. From 1895 to the date of his death he held the chair of Medical Diagnosis in the Indiana School of Medicine. A lover of nature, he was an active member of the Indiana Audubon Society, and president of the Indiana Nature Study Club. He was also a member of the committee to Collect Data on the Archeology of Indiana. He was not a seeker after preferment. Preferment sought him, and it ever came as a recognition of special fitness. He not only occupied the several positions above enumerated, but what is far more important, he filled each and all of them acceptably and ably. He was a peculiar combination of versatility, profound and thoroughgoing ability, and a genial and loving personality.

For many years he had spent much of his vacation periods in the mountains and in mountain climbing. He had climbed many of the great mountains of Switzerland and of America and was president of the American Alpine Club. It was while engaged in his favorite recreation, scaling Mt. Siyeh, in Glacier National Park, that he met death.

In his religious affiliations he was a member of the Meridian Street Methodist Episcopal Church, in Indianapolis. In his social and professional life, while he was positive and forceful in action, he was always courteous, kindly and considerate of the rights and of the feelings of others. Clean in thought, clean in speech, he was an honorable, an upright, and a Christian gentleman, with all which that title implies.

Frank B. Wynn was a contributor to periodicals and newspapers, writing popular, fascinating articles on mountain trips, etc. He was a compiler of songs used by the Nature Study Club. The booklet "Suggestive Plans, Indiana's Centennial Celebration, Nineteen Sixteen" was in large part the result of his work and interest.

Short non-technical papers included "The Mountain Queen" (dedicated to the Mazamas, July 4, 1915), "The Campfire", "Hail to Indiana", "My Boy", "Sleep", and others.

His more technical articles are in part, at least, as follows:

LIST OF PAPERS BY FRANK B. WYNN.

Some sanitary questions concerning tuberculosis. Trans. Ind. St. Med. Soc., 1896, p. 149.

Oral lesions of syphilis in relation to the public health. Trans. Ind. St. Med. Soc. 1898, p. 331.

Two cases of splenomedullary leukemia with specimens. Trans. Ind. St. Med. Soc. 1899, p. 154.

Report of committee on pathology. Trans. Ind. St. Med. Soc. 1899, p. 429.

Report of committee on pathology. Trans. Ind. St. Med. Soc. 1901, p. 542.

Report of committee on pathology of the Indiana State Medical Soc. 1902, p. 375.

The X-ray in the treatment of skin diseases. Trans. Ind. St. Med. Soc. 1903, p. 201.

Report on scientific exhibit, Indiana State Medical Society. Trans. Ind. St. Med. Soc. 1903, p. 315.

Human immunity in tuberculosis. Colo. St. Med. Jr. vol. 10, p. 116, 1904.

Digitalis and Cardiac Hypertrophy. Jr. Amer. Med. Assn. vol. 43, p. 164, 1904.

Report on the scientific exhibit. Jr. Amer. Med. Assn. vol. 43, p. 828, 1904.

Diagnosis and treatment of incipient skin cancer. Lancet-Clinic, vol. 55, p. 429, 1905.

Report on pathological exhibit. Trans. Ind. St. Med. Soc. 1905, p. 474.

Plexiform Neurofibroma. Jr. Amer. Med. Assn. vol. 46, p. 500, 1906.

X-ray treatment of skin tuberculosis. Amer. Jr. Derm. and Genito-Urinary Dis. vol. 10, p. 111, 1906.

Acetanilid poisoning. Jr. Amer. Med. Assn. vol. 49, p. 1037, 1907.

Report of a series of Leucemic cases, with brief comments on the symptomatology and treatment. Jr. Ind. Med. Assn. vol. 1, p. 58, 1908.

Tuberculosis exhibit and cabinet. Jr. Amer. Med. Assn. vol. 53, p. 946, 1909.

The psychic element in the causation and cure of disease. Jr. Ind. St. Med. Assn., vol. 2, p. 515, 1909.

Public health exhibits for permanent installation. Jr. Amer. Med. Assn. vol. 57, p. 1282, 1911.

Report of cases treated by "606". Jr. Ind. St. Med. Assn. vol. 4, p. 293, 1911.

Public health exhibits. Jr. Amer. Med. Assn. vol. 56, p. 294, 1913.

Our association and its activities. Some suggestions and plans for the success of the next annual meeting. Jr. Ind. St. Med. Assn. vol. 8, p. 1, 1915.

The necessity of co-ordinating methods in the definite diagnosis of pulmonary tuberculosis lesions. Jr. Ind. St. Med. Assn. vol. 10, p. 15, 1917.

Psychic factors in temperature, etc. Jr. Amer. Med. Assn. vol. 73, p. 31, July 5, 1919.

Renal tuberculosis. Its early recognition and management from the viewpoint of the internist. Jr. Ind. St. Med. Assn. vol. 14, p. 33, 1921.

The ten commandments of medical ethics. Indianapolis, 1922.

ROBERT W. McBRIDE.

ALEXANDER SMITH.

Edinburgh, Scotland, 1865. Edinburgh, Scotland, Sept. 9, 1922.

From Edinburgh, Scotland, his birthplace, comes the announcement of the death of Professor Alexander Smith, a distinguished and honored member of our Academy, lately head of the department of chemistry at Columbia University in New York.

About three years ago while addressing a class he was stricken with a fainting spell caused by the fatal malady. Shortly afterward he underwent operation for tumor of the stomach. The hoped for recovery with restoration to health did not come. He suffered intense depression and was an invalid from that time on. While the termination, on September 9, 1922, of the long and insidious illness which clouded his latter days was not unexpected, his loss is a heavy one for chemistry.

Alexander Smith, son of a well known musician of Edinburgh, had the advantage of the best chemical training available in Europe during his student days. He received the degree B.Sc. at the University of Edinburgh in 1886; the Ph.D. degree at the University of Munich, as a student of the master organic chemist, Adolph Von Baeyer, in 1889, and during 1890 served as assistant in chemistry in the University of Edinburgh.

Thus splendidly equipped for the work of a teacher of chemistry Smith came in the fall of 1891 to the professorship of chemistry in Wabash College at Crawfordsville, Indiana. He soon became identified with the science organizations of the State and was elected to membership in the Indiana Academy of Science at the December meeting 1891. During the years following he contributed much to the success of the annual meetings of the Academy, especially in the chemistry-physics section, through forceful discussion and through presentation of papers concerning his researches on 1:3 and 1:4 di-ketones, syntheses by means of potassium cyanide, and the constitution of calomel vapor.

Alexander Smith was a gentleman of polished manner, pleasing address and striking personality. As those who knew him will recollect, his clear and sparkling eye constituted a very conspicuous and characteristic feature.

His election to Fellowship in the Academy occurred in 1893 and our records show that he remained active until 1908 when his name was placed on the non-resident list of members, he having been called from Wabash College to a professorship in the University of Chicago in 1894.

The bibliography contains a long list of titles of published researches and text books. The researches on sulphur and on vapor pressure in 1912 won for him the Keith Prize from the Royal Society of Edinburgh.

Smith's sphere of influence in chemistry was perhaps widest as a great teacher and as author of pre-eminent text-books, such as his "Introduction to General Inorganic Chemistry", "General Chemistry for Colleges", "A Laboratory Outline of General Chemistry", and others.

"Proc. 38th Meeting, 1922 (1923)."

These texts have had wide use in English speaking countries and most of them have been translated into German, Russian, Italian, Portuguese, Spanish, Chinese, and even into Urdu.

It was while serving as Director of General and Physical Chemistry in the University of Chicago that his teaching methods were chiefly developed. In fact, his career at Chicago was brilliant and intensely active. In addition to teaching and administrative work within his department he served as Dean of the Junior College of Science and possessed energy in reserve to continue investigative work.

In 1911 he was called to Columbia University as head of the department of chemistry which he proceeded to reorganize and expand in a fundamental way. With his characteristic overflowing enthusiasm, industry and vitality he continued active until forced by illness to desist.

Alexander Smith's career was a brilliant one but all too short. American chemical history presents the names of but few chemists of such attainment in a generation.

LIST OF PAPERS BY ALEXANDER SMITH.

I. PUBLISHED INVESTIGATIONS.

(a) Organic Chemistry.

1. Thesis, Ueber 1, 3-Diketone. Munich, 1889. Beiträge zur Kenntniss der 1, 3-Diketone [with Prof. Claisen]. Liebig's Annalen, *277* (1893), 184-206.
2. On Desylacetophenone. Journal of the Chemical Society, *57* (1890), 643-652.
3. Ueber Condensation mittelst Cyankalium. Berichte der deutschen chemischen Gesellschaft, *26* (1892), 60-65.
4. Ueber die Condensation von Aceton mit Benzoin mittels Cyankalium. Berichte der deutschen chemischen Gesellschaft, *26* (1892), 65-71.
5. Two Stereo-isomeric Hydrazones of Benzoin [with J. H. Ransom]. Royal Society Edin., Proceedings, 1894, pp. 201-202; American Chemical Journal, *16* (1894), 108-115.
6. Die Einwirkung von Hydrazin und von Phenylhydrazin auf 1, 4-Diketone. Liebig's Annalen, *289* (1896), 310-337.
7. Condensation with Benzoin by Means of Sodium Ethylate [Thesis of J. B. Garner]. University of Chicago Press, 1897.
8. On the Phenylhydrazones of Benzoin. American Chemical Journal, *22* (1899), 198-207.
9. On Potassium Cyanide as a Condensing Agent. American Chemical Journal, *22* (1899), 249-256.
10. Notizen ueber die Einwirkung von Phenylhydrazin auf einige 1, 4-Diketone [with H. N. McCoy]. Berichte der deutschen chemischen Gesellschaft, *35* (1902), 2169-2171.

(b) Inorganic and Physical Chemistry.

11. Amorphous Sulphur and Its Relation to the Freezing Point of Liquid Sulphur [with W. B. Holmes]. Royal Society Edin., Proceedings, 1902, pp. 290-301; Decennial Publications of the University of Chicago, IX; Zeitschrift für Physikalische Chemie, *42* (1903), 469-480.
12. On Two Liquid States of Sulphur, S_μ and S_λ, and Their Transition Point [with W. B. Holmes and E. S. Hall]. Royal Society Edin., Proceedings, 1905, 588-589; Zeitschrift für Physikalische Chemie, *52*, 602-625.
13. The Nature of the Amorphous Sulphur, and Contributions to the Study of the Influence of Foreign Bodies on the Phenomena of Supercooling Observed When Melted Sulphur is Suddenly Chilled [with W. B. Holmes]. Royal Society Edin., Proceedings, 1905, 590-592; Berichte der deutschen chemischen Gesellschaft, *35* (1902), 2992-2994; Zeitschrift für Physikalische Chemie, *54*, 257-293.
14. Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers [with C. M. Carson]. Royal Society Edin., Proceedings, 1906, 352-356; Zeitschrift für Physikalische Chemie, *57*, 689-717.

15. Ueber den amorphen Schwefel: V. Das System Schwefel-Jod [with C. M. Carson]. Zeitschrift für Physikalische Chemie, *61* (1907), 200-208.
16. Amorphous Sulphur VI. Precipitated Sulphur [with R. H. Brownlee]. Royal Society Edin., Proceedings, 1907, 308-311; Zeitschrift für Physikalische Chemie, *61* (1917), 209-226.
17. The Solubilities of Ortho-phosphoric Acid and Its Hydrates, A New Hydrate [with A. W. C. Menzies]. Jour. Amer. Chem. Soc., *31* (1909), 1183-1191.
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III. ADDRESSES.

A large number of addresses, chiefly on various phases of the teaching of Chemistry, have been published in the School Review, School Science, and elsewhere.

IV. REVIEWS.

A large number of reviews of current books on Chemistry have been written for Science, The Journal of the American Chemical Society, School Science, The Journal of Physical Chemistry, The School Review, and other magazines.

ROBERT EDWARD LYONS,
Indiana University.

EARL JEROME GRIMES.

Russellville, Indiana,
January 15, 1893.

Williamsburg, Virginia.
December 15, 1921.

It seems to us, who cannot comprehend, that the most tragic irony of fate is for a young man to step into the Great Unknown just as he is beginning to realize his life's ambitions after conscientious and tireless effort to reach that goal. Thus came the untimely death of one of our younger members, Earl Jerome Grimes, December 15, 1921, at Williamsburg, Virginia.

Earl Jerome Grimes was born at Russellville, Indiana, January 15, 1893, the son of Charles F. and Izzie Anderson Grimes. To his parents he owed his simplicity of taste, his integrity, and his directness of speech as well as manner.

Even while in the grammar schools of the town of his birth he came under the influence of two of the members of this Academy, W. S. Blatchley and Charles C. Deam. In C. T. Malan, superintendent of the Russellville Schools, Mr. Grimes had a friend and confidant to whom he often presented the problems that arose in the early part of his career.

By the time he graduated from high school, in 1911, he had prepared a noteworthy collection of the flowering plants of Putnam County, as well as collections of reptiles, bird eggs and insects. Through his communion with the out-of-doors and through the help and encouragement given by those who appreciated the promise Mr. Grimes held, he developed into a keen and accurate observer, as well as a precise technician.

On graduating from high school, Mr. Grimes was forced to temporarily lay aside his ambition to go to college because of failing eyesight. Therefore, he entered the employment of the Department of Geology of the State of Indiana. Here, for two years, he was engaged in soil surveys conducted by that Department in co-operation with the Federal Bureau of Soils. In 1914, having accumulated sufficient funds by frugal living, and with his eyes improved, he entered Purdue University. Intermittently during the period from 1914 to February, 1916, he worked for the Federal Bureau of Soils and then entered the University of Illinois. Here, with the exception of the summer of 1917, he worked continuously until his graduation in 1918. For the excellence of his work at Illinois, Mr. Grimes was awarded "Final Honors", "Special Honors in Agriculture" and was elected to Sigma Xi.

May 28, 1918, a few days before graduation, Grimes enlisted in the army, going to Camp Taylor, Kentucky, two weeks later. He was commissioned second lieutenant of infantry August 26, and was selected for immediate foreign service. In September he sailed for France with the 84th Division. On the way across he contracted influenza which prevented his being sent to the front.

After the Armistice was signed he was made instructor in agriculture in the United States Army School at Le Mans. Later he went to

"Proc. 38th Meeting, 1922 (1923)."

London as a United States Army Student at the Imperial College of the University of London. There he spent four months, and also did some work at the Rothamsted Experiment Station.

June 26, 1919, he married Miss Eileen Jessie Whitehead, also a botanist and a member of the graduating class of the University of London.

Returning to America in July,, Mr. Grimes was honorably discharged from the army in August and soon after was appointed Associate Professor of Botany in the College of William and Mary at Williamsburg, Virginia. Here, until the time of his death, he conducted courses in General Botany, Taxonomy, Bacteriology, Plant Physiology, Plant Pathology, and Soils. Even his spare time he put to use in the field and made what is perhaps the largest and most complete collection of Virginia plants ever gathered. With this collection he has left his characteristic full and accurate notes so that the material may readily be worked up for publication.

In addition to being a member of the Indiana Academy of Science, which he joined in 1908, Mr. Grimes was also a member of the American Association for the Advancement of Science, American Society of Bacteriologists, Sigma Xi, and a charter member of the Association of Virginia Biologists. In his honor the students of biology at the College of William and Mary have joined his name with that of a great botanical collector of colonial days as the name of the biological society Mr. Grimes helped found—The Clayton-Grimes Biological Club.

In his death there passed an inspiring and sympathetic teacher, a tireless worker, a keen and accurate observer, a great botanist in the making.

Patient, persistent and determined, his brief span of life was one of achievement despite obstacles. It serves as a means of awakening us to the possibilities of human power—an inspiration to effective exertion.

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HARRY F. DIETZ.

PRESIDENT'S ADDRESS.

SOME PROBLEMS OF PLANT PHYSIOLOGY.

F. M. Andrews, Indiana University.

In the present paper only a few of the many interesting and important problems of plant physiology can be mentioned. The time at my disposal forbids, for the most part, even the briefest outline of these much-needed investigations, and permits me to make little more than a mere enumeration. To be sure, many of these problems have been objects of research on different occasions and they have been investigated carefully from various points of view. The writer has studied and written contributions on many of these problems some of which will be referred to later.

As one attacks a problem he must cautiously feel his way as if in the dark, for that is his status for the most part, at the beginning. Step by step he can move forward if all goes well. Frequently he finds himself completely baffled from the very first and is compelled to retreat. This retreat, however, should not deter him but rather should act as a stimulus which will cause him to recharge the next time with more foresight and determination. After one such failure he must often adopt an entirely different line and point of attack, and marshal his forces in a new formation. Very often a difficult problem must be approached first from one angle and then from another in order to see where an entering wedge may be driven. Finally, after persistent, well generaled, and conscientious attacks an impression will finally begin to be made and when the first wall has crumbled, and the first trenches have been crossed the remainder of the resistances of the problem will often surrender more easily. Other problems, however, will only succumb or be conquered by a state of siege and this the writer declares after many attempts in the research field. It is therefore for the earnest research man a declaration of war in the cause of science. In this worthy procedure the physiologist as well as other scientists should ask no quarter and should give none. In some investigations he can bide his time, but often the nature of the problem surrounds him with conditions over which he has no control. He therefore may not be able to complete a problem at once or by continuous prosecution, but, like many an artist, must await the return of proper scenery or conditions from day to day or even sometimes from year to year with its sunlight, shadows, and colors in order that the advance may be made under the proper conditions.

The writer's aim and efforts have been to elucidate wherever and whenever possible those truths of nature which of themselves constitute sufficient reward. In many lines of research, no absolutely continuous line of attack on a problem can be predetermined. Therefore the investigation must proceed according to the manner in which the problem behaves and the way in which it reacts to the conditions that surround it. As none of the many problems have been exhausted all

"Proc. 38th Meeting, 1922 (1923)."

can be further studied with profit. It is often quite worth while to record one's failures as well as one's successes in an investigation. This is frequently valuable for guidance in further research.

Often what at first seemed to be of chief importance in a problem turns out to be of minor value in comparison with later developments. New points of view or new problems present themselves as he progresses with his problem and crowd upon his attention to such an extent that a limitless field for investigation sooner or later presents itself for solution. The writer realizes that work of enormous value has already been accomplished and that greater discoveries are in store for the future. With this view in mind he now ventures to mention a few at least of the problems in plant physiology for further study.

If we direct our attention to the root system of plants we find that this subject has by no means received the attention which its importance deserves, notwithstanding the large amount of study that its various phases have received. As a root grows older it gradually loses its ability to absorb water, which function is constantly relegated to the young roots. The rapidity, however, that marks this change and the specific modifications that occur both in cell walls and protoplasts are worthy of study. The well known cases of root contraction include a number of interesting lines of investigation. Since neither osmotic pressure nor the activity of secondary growth causes variation in root contraction in different plants, the question of the character of the active cells both as to elasticity and also localized transformation requires close attention (1, Bd. II p. 17).

A root of Faba will exert a pressure of from 300 to 400 grams and will grow in clay, where it meets a resistance of 100 to 120 grams, almost as rapidly as in water (2). The writer has recently found that root growth of seedlings is not stopped by a water pressure of 600 atmospheres and that, although the root is rendered transparent in a fraction of a minute, it recovers in a few days when replanted.

The statolith theory, ingenious as it is, requires confirmation notwithstanding the galaxy of able investigators who have made contributions in its behalf. Various attempts have been made to explain geotropism by chemical change, and this has created a field of special interest. Němec found that the geotropic stimulus caused certain changes in the protoplasm. Long ago Kraus (3) showed that the amount of sugar increased on the lower side of a horizontal stem while the acidity decreased and that later both sugar and acid decreased. Kraus (4) also states that the percentage of sugar is increased in active shoots that are continually shaken but this has been questioned. Czapek (5) opened up a field for investigation on the chemical side by proving the formation of homogentisinic acid by the oxidation of tyrosin that were geotropically stimulated.

The character of the soil is an object of more thorough study, particularly with regard to the needs of certain plants whose roots often undergo extensive development. Nobbe (6) has shown that the roots of a wheat plant will total a length of 500-600 meters, while the roots of a squash plant may attain 25 kilometers or 15⅜ miles. It may be

readily seen that scarcely any part of the soil will escape penetration by one or more rootlets. Many relationships, symbiotic and otherwise, in connection with the root system await solution as are also various problems connected with the methods and effects of aeration.

The direction and rate of movement of water through the cortical cells of the root to the fibro vascular bundles still requires elucidation (7, p. 84). Roots generally are thicker the higher they arise from a stem (8, p. 126) but become smaller and smaller as they ramify through the soil. Here their function is chiefly one of absorption as can be shown by aniline dyes (1, Bd. I p. 134).

The ability of certain plant parts to again put out new roots is well known. "A leaf, however, of *Phaseolus multiflorus* cut off at the pulvinus" and put in water may form roots and live for months and this is also true of *Ficus elastica* (8, p. 164). This power is possessed by the cotyledons of various plants even if cut into pieces (8, p. 164). So we have here a line of study to ascertain the cause of these well known differences in plants. The germination of the seeds of citrus plants and the Cucurbitaceae within the closed fruit is not rare and may perhaps be due to temperature conditions. Even when the seeds turn green this may be due to pathogenic conditions, or to a disturbed state of nutrition (1, Bd. I. p. 318). That some plants form active chlorophyll in darkness is well known. Cotyledons make but little or no food while filled with reserve materials even if green (9, p. 596). Although sometimes colored when exposed to light, roots generally are colorless. Nevertheless in Menyanthes a small amount of chlorophyll is produced (8, p. 166).

The importance of root-hairs merits further study. Schwartz (10) has shown that there may be as many as 230 root hairs per square millimeter and that these increase the absorbing surface as much as 12 times. The location and development of the root hairs give an excellent indication of the capabilities of the root for absorption. Various external conditions influence their development. According to Schwartz they are absent in *Allium cepa, Cicer arietinum, Cucurbito pepo, Helianthus annuus, Phaseolus multiflorus, P. communis, Ricinus communis* and *Zea mays* when the plants are grown in water. Some water plants do not produce root hairs except when they send their roots into soil (11, p. 194). Some root hairs may branch and remain unicellular (11, p. 25) as those of *Brassica napus.* There is the question whether new root hairs are ever produced between pre-existing ones or whether they always arise acropetally (11, p. 195). Snow (12) and others (13) have made valuable contributions to this topic.

Great interest attaches to the pegged and smooth rhizoids of Marchantia. If, according to one view, the pegged ones increase the absorbing surface and are of no mechanical assistance, we must also consider seriously the theory of Kamerling as to the service of the gas bubbles. At any rate this matter deserves thorough investigation (11, p. 202). The work on an individual root hair is small and it has been estimated that each hair will only absorb about .000,001 milligram (14, p. 242). However, their united action is great. Many problems

await solution concerning the trichomes other than root hairs found in plants.

In Tortula the rhizoidal cross walls are oblique (11, p. 204) when first formed. It is by no means decided that in this plant and in other mosses this oblique position is for the purpose of offering the greatest amount of surface for diosmosis and conduction in the filament. Some roots that normally grow beneath the ground when cultivated in clear water are in certain instances positively heliotropic and in others negatively so. This shows an ability to respond to a stimulus and is not inherited by them according to Darwinian principles (14, p. 733). Notwithstanding the admirable researches of Czapek on the corrosive effect of roots, the nature of the various secretions is still undetermined (15, p. 107).

Such questions as the following have a physiological bearing: juxtaposed or superimposed apical cells; the length of time a procambium cell can produce new elements; the physiological significance of anthocyanin; and quantitative estimation of transpirational reduction by felted trichomes (11). The irritant of *Urtica dioica* formerly thought to be formic acid but now determined to be an albuminoid substance (11) should be studied in other representatives of the genus. Other problems are iridescent plates of the Rhodophyceae, velamen condensation, and the significance of oblique palisade tissue (11); and the cultivation of various embryos as shown by Hannig (16) and others.

The old question of the ascent of water is still unanswered notwithstanding all that has been done to solve it. Strasburger studied the problem and arrived at certain valuable conclusions (1, Bd. I, p. 207) but was not able to explain the situation and, like the "noteworthy experiments" of Dixon and Joly (17), left the question undecided. The theory of Sachs soon became untenable although the force of imbibition is sufficient for the purpose. The great force of imbibition is shown by the swelling of starch which according to Rodewald requires a pressure of 2,523 atmospheres to prevent it (1, Bd. I, p. 63). In dried seeds imbibition and osmosis work together. This force is sometimes made use of to split skulls for anatomical purposes (1, Bd. I, p. 63). This force is, however, small in comparison with the freezing expansion of water at —20° C. which would require a pressure of 13,000 atmospheres to keep ice from forming (1, Bd. I, p. 29). Thus, we have the reason for the formation of frost rifts in the wood of various trees. These rifts are mostly radial and along the lines of least resistance (1, Bd. I, p. 307). The loud pistol-like reports often heard in living timber during extended and very cold weather indicate the formation of these rifts. The question of pressure affects even the plant when growing for it was first shown by Hales and afterwards by Kraus (1, Bd. I, p. 74) "that tree stems and fruits swell slightly at night and decrease in the day time due to transpiration although such changes in tree trunks are generally less than one per cent."

Other questions that crowd themselves on our attention are: the pressure necessary to close bordered pits; the physiological importance of tyloses; certain functions of leptome parenchyma, especially in relation

to the laticiferous system; the significance of the Casparian strips; and the meaning of guard cell fusion in Azolla and Funaria (11). Haberlandt was able to grow sporangia of Funaria in a culture solution for three weeks during which time normal spores were formed thus showing the efficiency of the chlorophyll system (11). The so-called secretion of wax by certain stomata requires further study (11). Uncertainty exists with reference to the secretions of certain glands as capitate and scutate ones (11) and elaioplasts (18). Objections have been offered to Tyndall's (11) interesting investigations concerning a layer of air saturated with ethereal oil which it is argued protects the parts concerned against heat, cold, or excessive transpiration. Do enzyme reservoirs contain protein material in addition to the enzyme (11)? Why are such large amounts of lime required for plants with cystolithic structures (11)?

There is the difficult problem of the dehiscence and cohesion mechanism of anthers, sporangia and other structures (11) which has occupied the attention of so many observers and has been so often the topic of research. Although these cases are of a physical nature, they are also of physiological interest and are still partly unsolved. The immense amount of work done on living motor tissues in the Urticaceae, *Stylidium adnatum*, and *Cyclanthera explodens* leave many points in doubt (11). It is moreover, remarkable that tactile pits have thus far been found in the walls of sensory cells only in the Curcurbitaceae and possibly also the Sapindaceae and tactile papillae only in floral organs and tendrils (11). The work on tactile organs of carnivorous plants, first recognized by Edwards in 1804, (11) leaves much to be done. In *Drosera rotundifolia*, Darwin found that a hair weighing .000822 milligram produced a noticeable reaction (1, Bd. II, p. 461) while, according to Kemmler, the least weight that will produce a stimulus on a sensitive skin is .002 milligram (1, Bd. II, p. 423). The causes of certain changes in the rate of growth of tendrils are unknown (1, Bd. II, p. 443). The epidermal lens cells of the epidermis as studied by Haberlandt present an interesting field worthy of further study. His photographs of a portion of a microscope made in connection with one of the membrane lenses show their capabilities (19).

The transmission of stimuli varies according to the kind of stimulus. Thus, Czapek (20) and others state that geotropic and heliotropic stimuli travel two millimeters in five minutes. Traumatic stimuli, according to Kretschmar (21) travel one to two centimeters per minute and Fitting (22) gives the rate as one to two centimeters per second for the tendrils of *Passiflora coerulea*. In *Mimuosa pudica* the velocity is about 1.5 centimeter per second (11). Questions as to the exact part played by the protoplasmic threads between the protoplasts are unanswered. Chemical stimuli in Drosera are transmitted only about ten millimeters per minute. Darwin found that .000423 milligram of ammonium phosphate would cause curvature of a tentacle (1, Bd. II, p. 463). The question remains as to what response if any is due to external causes. The origin of certain stimulatory movements is also

obscure. The quick movement of cilia after a stimulus shows its rapid propagation.

Physiologists differ as to the origin of excentric growth in roots and branches (11). The question of annual rings still awaits a solution (1, Bd. II, p. 274) along with certain ribbon shaped stems (11). On the subject of osmosis and plasmolysis, various questions remain for solution. How does a diatom retain its form in spite of the internal hydrostatic pressure (1, Bd. I, p. 122)? In the case of plants whose roots have been killed by heat the stems may remain living for several days but no experiments have as yet been made on their transpirational behavior. No exact work has been done to ascertain the influence of external agencies on the excretion of water pores. Similarly, doubt still surrounds the methods of sugar secretion by glandular cells and the means by which gland cells escape injury by high osmotic forces (1, Bd. I, p. 265) and other factors notwithstanding the large amount of excellent work that has been done on the subject.

The objections to the plasmolytic method are negatived in as much as verification of the method is easily obtained in various ways. Ostwald (23) has given an illustration of the membrane concerned and osmotic pressure in a theoretical way. The cryoscopic and other methods give results of great value. De Vries used the plasmolytic method to determine the molecular weight of raffinose and his results have since been confirmed (24). Moreover the work of Pfeffer has been confirmed again recently by Morse (25) and others who have made notable contributions to the subject. Among these the work of Fitting and Renner may be mentioned. Various questions arise concerning the conditions, under which natural plasmolysis occurs. Although a new cell wall may sometimes form around a plasmolysed cell which may remain living from a few hours to several weeks, nevertheless permanent plasmolysis produced and maintained artificially always finally causes death (1, Bd. II, p. 331). The specific difference in these cases deserves careful study. Taking the work of Pfeffer as a basis, Van Hoff founded his well known theory. Van Hoff also discovered the R. G. T. rule concerning chemical reactions and Kanitz showed its applicability for various cell activities (20). Recently much work has been done on osmotic pressure from a quantitative standpoint, on osmotic equilibrium, on permeability of organic membranes that are not protoplasmic in character, on the magnitudes of osmotic pressures and electrical conductivity and on osmotic pressure as it relates to distribution, morphology and growth (26).

With regard to the protoplasm numerous questions of direct physiological importance remain unsolved. For example, questions concerning cohesion and viscosity as well as the variation in surface tension need elucidation. Much interest also attaches to the various theories of protoplasmic streaming and much remains to be done concerning the effect of different chemical substances and other conditions (27). Temperature combinations with certain anaesthetics require attention. The locomotion of various diatoms and ciliated spores about which certain points are not clear is more rapid in proportion to their size than any

of our vessels that move on water. The recent valuable list of papers by Haberlandt on "The Physiology of Cell-Division" deserves consideration in this connection.

Overton (28) presented a rather plausible theory concerning the permeability of the protoplasmic membrane which was afterwards supposedly confirmed (29). Later studies, however, have thrown a cloud of uncertainty over his rather ingenious theory and further study of this important subject is necessary. The question of the penetration of aniline dyes into the living protoplasm was worked out by Pfeffer (30). The exact way in which an accumulation of dye occurs in certain plants remains to be explained.

Pfeffer's (30, Bd. I and II) work on chemotaxis is also of far-reaching importance. From the osmotactic standpoint the question arises concerning a tactic or phobic response in strong solutions. Spermatozoids and bacteria (1, Bd. II, p. 813) were caused to enter a capillary tube containing only .00000001 milligram of malic acid or peptone. Relatively, these amounts are not so small as they would seem since the sperms weigh only about .00000025 milligram and a cell of "*Bacterium termo*" about .000000002 milligram. On the other hand stronger solutions having an osmotic value of 0.5 per cent KNO_3 produce negative osmotaxis (1, Bd. II, p. 813). Englemann has introduced an excellent method of demonstrating chemotaxis in which certain organisms such as "*Bacterium termo*," *Spirillum undula* and *Spirillum tenue* are used. By his delicate test .000000001 milligram of oxygen can be detected (1, Bd. I, p. 292).

In the various processes of growth interest attaches in many ways. The position of the nucleus in growing parts such as root hairs may not always be in the most active part of the cell as the writer has shown. The rapid growth of certain plants or plant parts is well known. It is estimated that "a bacterium can under favorable conditions divide in 20 to 30 minutes. At this rate in three days 4,772 trillions of individuals would be produced."

Can all plants live when continuously illuminated? Plants in the polar regions do this and McKinney has shown that a certain amount of continued illumination is without effect (31, p. 222).

Growth may be checked locally by cold and still continue at other points. This was well shown by introducing the top of a defoliated clematis plant into a hothouse. Leaves were formed on the stem in the greenhouse while the part outside was still frozen and dormant (32). This development of transpiring leaves proved that in spite of the low temperature outside a large amount of water was absorbed by the roots from the frozen soil and carried through the stem. Knight long ago demonstrated that a plant exposed to transitory cold sprouted earlier than those maintained continuously in a greenhouse. The same phenomenon was observed by Pfeffer in various plants and by Müller-Thurgau in potato tubers (1, Bd. II, p. 266). Molisch reports that potato tubers placed at once in an ice box for 14 days at +1 to 3°C will grow at once if planted in a warm house. In case of an early variety one may thus obtain two crops in the same year (33, p. 272). Plants

growing in northern regions, ripen as a rule in a shorter time and here the question of illumination or other causative factors requires further study.

Many deciduous plants continue to cast off leaves and form new ones even when removed from temperate zones to the tropics. Oaks and beeches never cease to do this, while others such as the cherry gradually become evergreen in Ceylon but cease to bear flowers. The peach, on the other hand, produces flowers and fruit during the entire year (1, Bd. II, p. 271). Experiments of this kind are much to be desired in temperate climates where artificial conditions could be supplied. It is difficult or impossible to cause many plants to bloom out of season while others lend themselves more or less to the process of forcing. However, artificial forcing causes abnormal development in some plants, as in the case of Lily of the Valley which is caused to develop the flowers before the leaves (7, p. 238).

A good many questions are concerned in the solution of certain points connected with periodicity. The experiments of Johannsen (34) show that treatment with ether or chloroform for 12 to 24 hours will cause the buds of such plants as *Syringa vulgaris* and *Prunus triloba* to open three to six weeks earlier than the plants not so treated and the activity of various functions was increased. Elfing and Lauren had observed before this that ether or chloroform increased respiration if the doses were not too strong, although this has been questioned. Molisch (35) has shown that if certain plants are immersed in water at 30° to 35° C, for 10 to 12 hours the resting period may be terminated. For example, a hazel branch one side of which was subjected to warm water bloomed in nine days while the other side which was untreated was still in the resting condition. *Forsythia suspensa* bloomed in 12 days after such treatment while the control was still unopen. Syringa bloomed 40 days after the warm bath while the control was still dormant. The responses shown in these experiments leaves certain questions unanswered.

Fitting's experiments (36) with *Erodium gruinum* and *E. ciconium* are interesting in this connection. He found that when, on a cool morning, deep blue flowers of these species were put in a box having a temperature of 40° to 42° there occurred quickly a sudden change of color. Within three seconds the blue flowers changed to a light rose and a few minutes later to a bright red. When returned to a cool place the blue color soon returned. Furthermore, the reaction of the cell sap is often indicated by the color of various living cells. Thus, the red color of rose petals and beet-roots shows that the cell sap is acid while the blue color of the hyacinth, blue bell, or cranberry shows that the sap is neutral or slightly alkaline (1, Bd. I, p. 490). We also have striking color changes caused by oxidases. Among these is the brown color assumed by the exposed flesh of apples, the prussian blue shown by Boletus when broken and the dark color of raw rubber (37, p. 390). The oxidation of the sap of Rhus to a black lacquer varnish in air by laccase is also well known.

Other properties of the enzymes are noteworthy. The dried sub-

stance of diastase, protease and ereptase of wheat and barley may retain its activity for 20 years and after the power of germination is lost (37, p. 390). Finely divided platinum and iridium among inorganic substances cause a catalytic action resembling that of enzymes. Buchner's discovery that the filtered sap of yeast plants can change sugar to alcohol and carbon dioxide, is interesting in this connection. The capability of diastase to hydrolize 10,000 times its volume of starch and invert 100,000 times its volume of sugar shows its great power. The yeast plant itself is active in various ways; thus it can reproduce 20 or 30 times in the absence of oxygen, it can produce alcohol up to 14 per cent before the yeast plant is killed, and it may produce a pressure of 25 atmospheres of carbon dioxide in a closed vessel before such action ceases (1, Bd. I, p. 576). Nägeli (38) estimates that the volume of a cell of beer yeast is about .000002 cubic centimeter and weighs about .0000005 milligram. The great numbers, however, make up for their diminutive size.

Bacteria also show activity in some of these directions. A closed flask, for example, containing a nutrient solution colored with indigo carmine and inoculated with certain bacteria will lose the blue color due to the removal of every trace of oxygen by the bacteria. On readmitting oxygen the blue color will return. In proportion to their bulk some bacteria may use oxygen 200 times as fast as man (1, Bd. I, p. 526). Certain bacteria will live in carbon dioxide under 50 atmospheres of pressure and may burst tin cans of conserves by developing such gas pressures. Small amounts of carbon dioxide thus given off may be estimated conveniently by a method given by Hempel (39) and extremely small amounts of carbon dioxide can be detected by the biometric method for seeds and other objects as devised by Tashiro (40).

The subject of phosphorescence presents an interesting field for investigation. For the already voluminous literature, one is cited to the recent work of Czapek (41), Molisch (42), and other contributors. Whether one holds to the extracellular, intracellular, or other theory regarding the production of light in different plant forms, various questions arise. The sudden increase or decrease in the strength of the light emitted requires explanation, as does the effect of different pressures of oxygen and the actual oxygen consumption by the organism in its formation of light. The light intensity may be sufficient to produce clear photographs of various objects, to produce heliotropic curvatures, and to read by, especially when "bacterial lamps" (42) are used, and is equivalent to about .000785 of a Hefner unit per square meter. The meaning of the necessity of a large amount of sodium for luminous bacteria is important as is also non-motility and light production in certain forms (31, p. 213).

Many interesting points regarding diffusion await solution. The diffusion of gases ordinarily takes place comparatively slowly as shown by Clausius (43, Bd. 3, p. 753) in connection with whose work the theory of diffusion by Maxwell was founded. Ewart (44) has shown that in certain cases diffusion causes the distribution of substances more rapidly than streaming. Osmotic pressure varies only slightly

(45) in plant cells within the temperature range ordinarily present, for a rise of only 15° C. causes a pressure change from 100 to 105.5 (1, Bd. I, p. 120) and this, to a degree, follows the laws of gaseous pressure (46). Brown and Escombe have opened up an interesting field in showing that the diffusion of CO_2 is not dependent on the size of the leaf pores but is proportional to their diameter (47). In like manner the diffusion of CO_2 as first shown by Graham constitutes an interesting topic. A study of diffusion in gelatine as investigated by Hüfner and Hagenbach (43, Bd. I. p. 445) and compared to protoplasm would be of value. Further studies are needed concerning the behavior of certain cell walls to the diffusion of liquids and gases. Conduction of food materials takes place rapidly in some parts, but is prevented entirely by girdling. The length of life, however, of that part of a tree above the girdle varies.

Many problems remain concerning the storage of food. Trees for example, are distinguished from annuals because the latter store their reserves permanently only in the seeds, and they differ from perennials because the latter store their reserves subterraneanly (48, p. 225). Many problems arise concerning the nitrogen question, particularly regarding autotrophic plants. There is the question of nitrites and nitrates and especially a question of nitrites in developing green plants. Questions arise concerning vegetable proteids and their synthesis, under certain conditions and points relating to sulphur. Plants of *Chenopodium vulvaria* and flowers of *Crataegus oxyacantha* evolve a nitrogenous compound in such quantity that a glass rod dipped in hydrochloric acid emits fumes when brought under a bell jar with such specimens. Wicke says this substance is trimethylamine in Chenopodium (49). The nitrogen problem is one requiring investigation by both physiologist and chemist.

Ethereal oils constitute a question. In *Dictamnus albus* the oil may vaporize to such an extent as to ignite when a flame is brought near it and hence many such flowers may be more fragrant at night (1, Bd. I, p. 502). In the daytime, however, the change in the diathermanicity of the air which would assist in reducing the heat of the sun's rays would be slight notwithstanding the efficiency of these vapors in that respect as mentioned above (50 and I, Bd. II, p. 848). Green and other colored leaves can absorb 50 to 90 per cent of the sun's energy (50). Certain species of Citrus possess highly inflammable oil. Among cryptogams the oily nature of certain parts is well known. In Lycopodium the spores flash into a beautiful array of scintillations on ignition, hence their frequent use in pyrotechnical displays.

Oligodynamic studies will bear further inquiry. Grafe has made valuable studies on cell chemistry and Haas and Hill have recently mentioned various metabolic problems (51). Electro-culture and the physiology of seedlings are worth-while problems. In 1878 Sachs stated that an electric current passed from the stigma to the ovary pedicel of Berberis stimulated all the stamens, but when sent in the reverse direction no stimulation was produced (14, p. 685). Other stimuli produce comparable results, for when plants are passed from dark to light and vice versa the stimulation is different (1, Bd. II, p. 504).

A stimulus may be positive at one intensity and negative at another. Geotropism is positive for most roots although moisture conditions may reverse this reaction. Most stems are positively heliotropic but in Linaria this undergoes a natural reversal since the young flower stems are positively heliotropic, becoming negative as they elongate (52, p. 318). Agapanthus and Papaver are similar examples.

Questions of symbiosis and metabiosis also arise. Just as numerous questions presented themselves concerning photosynthesis, we also have the field of chemosynthesis with many unsolved problems. Sugar may constitute a product both in constructive and in destructive metabolism and hence a physiological and chemical classification will not agree (48, p. 262). Questions have arisen concerning the wave length of light best for green plants. Pfeffer gives it as between Frauenhofer's lines C and D of the spectrum and of 660-680 uu wave length (1, Bd. I, p. 330). Reinke's (53) spectrophore can displace diffraction grating in certain experiments of this kind. The growing of lichens on windows of houses and their mechanical action shows unusual capabilities (54).

The prevention of flower wilting by the use of $PbNO_3$ deserves further study (55). The change of color of flowers due to a change of temperature, as above referred to, has a partial parallel in the enantiotropic substance, mercury iodide, and a further striking parallel in the double salt $Cu_2\ I_2\ 2HgI$ which changes color from red to brown and to red again on cooling (56). Though not analogous the sudden darkening of the pulvinus of Mimosa after stimulation shows that water has taken the place formerly occupied by air (57). A continued study of Schumann, Roentgen and other rays as well as different colored lights in various combinations of temperature and gases would net further valuable results.

Certain problems concerning the chemical action of different plants need further attention as that of wood destroying fungi; the penetration of structures by bacteria as egg-shells (58); the reported corrosion of stone, mollusk shells, oyster shells, and oolitic iron by algae (41, 1920, Bd. II, p. 360); and the penetration of membranes by fungal filaments (59). The unusual reported case of algae growing on a painting for about 200 years shows the capabilities in certain directions (60). Of the halogen group iodine and bromine are found in marine plants, as would be expected and probably in land plants (1, Bd. I, p. 433) though the latter is contradicted by Fresenius (61, p. 542). Other questions arise on this point. Lead is often present in plants but a practical method for its volumetric estimation is lacking according to Fresenius (62) and Sutton (63) advises weighing for its accurate determination. The chemist can assist in the many plant problems by determining substances in plants, but he cannot tell what ones and the amounts necessary for the proper functioning of the metabolic processes. This the plant physiologist must determine by actual experiment.

Facts in physiology once established are often disbelieved or forgotten. For example, the neglected work of Ingenhousz on the obtaining of carbon by green plants was afterwards brought to light by Liebig; the water-culture method first used by Woodward was subsequently

resuscitated by Sachs (1, Bd. I, p. 412). Many such examples in physiology could be mentioned. The forgotten work of Mendal was resuscitated by de Vries, Correns and Tschermak almost simultaneously (48, p. 504) and also the restoration of the now famous work of Conrad Sprengel by C. Darwin.

Then there is the physical question of the Brownian movement, long known and of interest to all scientists. The chemist also looks for forms of energy in the atom by a rearrangement of the protons and electrons and the energy of radioactive substances (64). The determination of Hydrogen Ions much referred to, especially of late, presents many questions which the botanist would do well to work in conjunction with the chemist. The sensitiveness of the bacteria method, above referred to, exceeds that of various chemical methods ordinarily employed (65) and hence its extreme usefulness to the physiologist.

The chemistry of plant odors presents many problems. Many plants, such as *Ageratum mexicanum*, have no special odor during life but when killed by drying, freezing, or heating to 60° C., they give off a very pleasant odor of cumarin (33, p. 274). Similar odors appear in *Asperula odorata*, *Anthoxanthum odoratum*, *Prunus cerasus* and vanilla plants and the well known instances of hay and other plant odors. We can smell .000002 milligram of oil of roses and .000000002 milligram of mercaptan (66, p. 97). The topic of transpiration presents many problems. Hales (67) proved that the flow of water may be reversed in a stem and Strasburger verified this by cutting off a tree trunk near the base and which was naturally grafted about one meter above the cut. The cut-off stem remained fresh for years (68). A summarization of transpiration and the literature is given by Burgerstein (69) up to 1920.

There remain questions about carbohydrates and fats. In some plants no starch is formed in the chloroplast (52, p. 223) and in others cane sugar formation precedes that of starch. Questions arise concerning the absence of some polysaccharides in certain plants and some doubt still exists on the functions of mono-di- and poly-saccharides (1, Bd. I, p. 468).

Carbon is necessary for the metabolism of plants and as Noll says, no other element can enter into the formation of so many and such a diversity of substances in the organism or in the chemical laboratory (70). A reference to the works of Richter and Beilstein will substantiate this fact. According to Chamberlain (71) the number of carbon compounds now exceeds 200,000.

The well known process of abscission or leaf-fall can be brought about in various ways. Further research is needed to determine whether the production of organic acids is actually operative at the end of the summer according to Wiesner's view or if organic acids may have any influence (1, Bd. II, p. 278). In this connection it is interesting to recall the work of E. Hannig on the casting off of flowers as a result of external conditions and the field for investigation brought to light by his experiments. Several points concerning the action of poison by increasing the temperature as well as the differences in the resistance

of plants to heat require study. Pouchet found that the seeds of Medicago would germinate after boiling in water for four hours (1, Bd. II, p. 294) while the seeds, from stone fruits that have been made into jam, germinated (9, Vol. II, p. 230). The subject of desiccation leaves numerous questions to be settled. Much attention has been given to a study of the effect of freezing on plants but still it is not known why freezing kills some plants and does not affect others. The resistance of bacteria to freezing requires further explanation (1, Bd. II, p. 314). The resistance of trees which form oil in cold weather as well as the ability of the same plants to withstand cold at different stages of their development needs solution (1, Bd. II, p. 317). A single reference to the work of Müller-Thurgau, Molisch, Göppert, Winkler and Kylin must suffice here. This topic forms a subject of great interest and its value can hardly be over-estimated. Even in reasonably cool situations plants may sometimes be injured by drops of water which concentrate the sun's rays. The resistance of certain marine algae which grow at -1.8° C. requires attention, as does the statement that the spores and mycelia of Mucor are equally resistant, and whether or not ice forms in turgid bacterium cells (1, Bd. II, p. 310).

Dry spores such as those of Aspergillus and yeast are only slightly or not at all injured by submergence in absolute alcohol, ether, benzol or carbon dioxide. The point now arises how they would compare with spores in air (1, Bd. II, p. 324). Do roots of seedlings require gradual moistening to recover and live after drying (1, Bd. II, p. 324)? A further comparative study of the spores of bacteria and seeds would net additional worthy results. Notwithstanding what has been done on the effect of different alkaloids and on the various poisonous plant substances, there remain many problems for investigation by the physiologist.

Certain questions concerning the germination of seeds and the subsequent transfer of materials require investigation. There are questions of cortical and medullar functions which need attention. Schimper (72) has shown that the bundle sheaths in Plantago could convey substances, but less rapidly, after the removal of the fibro vascular bundles. In young tissues the Biuret reaction is useful in showing the disappearance of certain substances, as soluble proteids. Companion cells need study and the questions concerning latex are by no means settled. The writer by depriving the seedlings of Papaver of their latex checked the growth but did not kill the seedlings. The same experiment the author has performed on certain sieve tubes with similar results. Schwendener states that no latex escapes from withered plants or old parts when cut (1, Bd. I, p. 594).

If nine tenths of all phanerogamic seeds possess oil, as Nägeli states, it can be seen that this does not necessarily protect them from desiccation. (1, Bd. I, p. 609.) Puriewitsch and others planted grains of certain plants from which the embryo had been removed and the endosperm was neither changed to sugar nor removed. When, however, the place of the embryo was taken by substituting a small cylinder of gypsum whose lower end reached into water, to remove the forming

sugar, the starch was completely removed from grains of maize or other plants (73).

In the field of microchemistry much of interest to the plant physiologist remains to be done. This work has been ably carried out, especially by Tunmann (74) and Molisch (75). The application of chemistry should go hand in hand with plant physiology. As we glance through the latter subject we see, as a rule, far too little of the use and knowledge of chemistry. The masterful work of Czapek (41) and others have rendered service of great value along this line. With this brief idea of physiology's great helper we turn our attention in conclusion to some special problems where it is concerned.

A change took place in chemistry when Wöhler in 1828 obtained urea from ammonium cyanate and thus produced for the first time an organic from an inorganic compound. Then Kolbe synthesized trichloracetic acid in 1845 and Berthelot synthesized alcohol from formic acid thus removing the boundary between organic and inorganic chemistry (76). Organic chemistry, the chemistry of carbon compounds, has tried to do what plants do, and in many cases has apparently succeeded. The plant no longer furnishes alizarin and indigotin for commerce which are now obtained from coal tar and even some alkaloids have been prepared artificially.

Since colloids were first investigated by Graham the similar nature of protoplasm has given their study a significance. Later the principle of Tyndall's phenomenon was applied by Zsigmondy to the so-called ultramicroscope so that protoplasm and living cells can be studied to advantage. Recently Czapek (77) has investigated the question of surface tension in plant cells and has called attention to the application of Richardson's Law. We have to do here especially with the behavior of two important substances in the plant cell, protoplasm and chlorophyll. Their activities go hand in hand in green plants. We shall now turn our attention to the behavior of the chlorophyll in particular. Glancing backward we recall that the green coloring substance of plants was recognized by Nehemiah Grew (78) in 1682 and that it was given the name of chlorophyll in 1817 by Pelletier and Caventon (41, Bd. I, p. 556). Numerous and valuable contributions have been produced in rapid succession and yet almost 250 years after Grew's work the performances of this riddle are unsolved. Colored lights have an effect on certain plants, for it is claimed that in red light specimens of Oscillatoria become green, in green light they turn red and in blue light assume a yellow hue (79, p. 245). Problems in great number remain to be answered as questions concerning a chloroplast membrane and the influence of chloroplasts on various cytoplasmic movements (79, p. 251). The positions assumed by chloroplasts so ably investigated by Stahl and Senn (80) still leave many points to be solved. The question of structure in certain respects is still doubtful as is the exact form of the chlorophyll in the chloroplast and points concerning yellow pigments (1, Bd. I, p. 297).

The greatest advances on the subject of chlorophyll so far are the investigations of Willstätter and Stoll (81). Their published papers deal

with the chemical side of the question and are of such great importance that they are indispensable to an understanding of the subject. But the function of chloroplasts interests us most. Among the questions are the formation of starch and other substances; the first-formed products; is the same course always followed in sugar production; and the chemistry of pigments. Can oil produce starch or vice versa in the chloroplast independently of the cytoplasm? Are glucosides direct products of photosynthesis? Further studies should be made on the retarding influence of higher carbon dioxide percentages and on the more or less complete loss of photosynthetic power by normal chloroplasts. Is the protoplasm of heliophobic plants more sensitive to light than the chloroplast? (1, Bd. I, p. 285.)

The evolution of oxygen from water plants directed the attention of Ingenhousz to the photosynthetic processes in green plants and his work in connection with that of Senebier and De Saussure constitutes one of the most important scientific discoveries. Iron is necessary to chlorophyll formation, but the action of iron and alum in causing the reddish flowers of Hydrangia to become blue is uncertain (1, Bd. I, p. 421). Chemical reactions often occur with great velocity. So we may have an immediate cessation or recommencement of oxygen evolution in green plants as shown by the extremely sensitive bacteria method. In light, starch (1, Bd. I, p. 303) is produced in five minutes in considerable amount in Spirogyra which previously was starchless (82). Detmer has shown that the iodine reaction of starch can not be obtained in distilled water (83). No means of stabilizing this reaction is known. We have a great many chemical changes occurring in tiny green cells whose total volume often does not equal 0.1 cubic millimeter. Since the air contains only .03 to .04 per cent of carbon dioxide the work necessary on the part of the green plant to make its food will be easily understood.

Light we know is necessary for chlorophyll action, therefore it is not surprising that moonlight which is about 1 600000 the strength of sunlight would prevent the handling of CO_2 and even with light of 0.1 to 0.025 the strength of sunlight respiration and photosynthesis about balance (1, Bd. I, p. 323). Plants in dwellings often suffer from deficient light since at 0.5 meter from a window the plant gets only 0.3 and at a distance of two meters only 0.08 of the light it would get in the open sunlight (1, Bd. I, p. 323). When the sunlight falls on a thin green leaf most of the energy is usually absorbed so that the light which passes through would not cause the formation of starch nor an evolution of gas (1, Bd. I, p. 329). Copper beeches due to their color and light interference grow more slowly than vividly green species, other conditions being equal (84). An oleander leaf will produce per square meter in sunlight about 0.000535 gram of starch in one second, obtaining thereby energy equivalent to 2.2 caloric units, which is less than one per cent of the energy of the sunlight (84). Under good conditions other plants such as the pumpkin may produce in 15 hours 25 grams of starch per square meter (85) which necessitates the removal of the carbon dioxide from 50 cubic meters of air. The quantitative

activity of the green plant is therefore easily realized. Recently studies have been made concerning carbohydrate substances of Thallophytes, Bryophytes and leaves of Angiosperms and methods for their estimation in the extracts (86). The amount of chlorophyll is really very small per unit area and Tschirch has estimated that only 0.1 to 0.2 gram is usually present per square meter of green leaf surface. Much work remains to be done on chlorophyll activities with various autotrophic plants of different colors and under different conditions of light composition. Marine plants suffer from light conditions as the water deepens and at a depth of 400 meters in the sea autotrophic plants cease to exist (1, Bd. I, p. 337). The chloroplasts of some plants can continue to live and carry on the process of photosynthesis for a short time when removed from the cell (87), but all attempts to grow them outside of the cell permanently have failed. The chlorophyll of green plants breaks down in solution. Wahmsley (88) states that he has preserved a specimen of Draparnaldia in camphor water for 20 years and that the chlorophyll remains unchanged. This, however, says nothing as to the actual preservation of the chlorophyll itself. Concerning those substances which form the chlorophyll only a faint intimation exists which creates a wide field for study.

A large field for investigation is brought out by Fitting in his interesting paper on a new branch of physiology which he names "Geographical Physiology" (89). The various theories concerning carbon dioxide assimilation have been well summarized by Schroeder (90). One which is much quoted may be mentioned, namely Bayer's Theory "according to which formic aldehyde is produced from carbon dioxide and water in the chloroplast, oxygen being evolved, and carbohydrates resulting by polymerization" (1, Bd. I, p. 340). Doubt attaches to this theory. More recently Ewart states "that not formaldehyde but a biose sugar is the first product in photosynthesis and the traces of formaldehyde which have been detected in green plants are the result of the destructive photo-oxidation of chlorophyll and are formed equally well in the entire absence of carbon dioxide when extracted chlorophyll is exposed to light" (91). Attention is also directed to the question of photosynthesis and the Electronic Theory (92).

Professor Giacomo Ciamician of Bologna, Italy, made an interesting address some years ago in New York which has a bearing in this connection. He asked "why use only the fossil energy of the sun—for that is what we do when we burn coal! Why should not man use sun power, direct, as do plants and trees?" (93) According to one estimate he made, the sun delivers in energy by means of its rays enough power in six hours to equal 2,500 tons of coal per square mile. We mine in the U. S. about 600,000,000 tons of coal per year while the Sahara Desert receives daily in solar energy the equivalent of 6,000,000,000 tons of coal every day. He indicated by a long list of chemical processes the probability of the consummation of his ideas and prophesied a trend toward the tropics which would on this account become thickly populated in time. Slosson says "man takes a 1,000 horse power engine and an electric furnace at a temperature of several thousand degrees to get

carbon into combination with hydrogen, yet the little green leaf in the sunshine does it quietly and without getting hot" (66, p. 239).

One of the tasks of the future is to ascertain, therefore, if possible, the various ways by means of which green plants make their food substances and to follow out the chain of processes completely. Green plants get their energy from the sunlight and build up their structure. They have done this in past ages, and of this we have an expression in coal deposits, which are of proved vegetable origin (94). A knowledge of these various plant processes is all the more important since our timber supply is virtually gone. When we burn wood we release the energy of the sunlight which was stored up in the plant by the process of photosynthesis. By this transformation of potential into kinetic energy the activities of the green plant are reversed. And when we burn coal, formed as above indicated by green plants, which collected the sun's rays of many thousands of years ago and stored them, we release this energy in the form of heat by the process of combustion. And so with our forests, nearing exhaustion as a fuel resource and the end of our available coal in sight we realize that some other source of energy must ultimately be obtained. The recent coal strike furnished sufficient evidence to convince the railroads and other industries that coal was necessary to keep them in operation. Possibly a successful study of the various chemical and other processes of the chloroplast will later assist in throwing some light on this very important subject. With these suggestions and indicated problems some of which are old, many recent, and others in progress, some idea may be gained of the numerous opportunities for study which the subject of plant physiology offers.

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FRANCIS GALTON, LIFE AND WORK.

ROBERT HESSLER, Indianapolis.

Francis Galton was born one hundred years ago near Birmingham, England. Early in life he took up work in neglected fields. He became a great man of science and developed Eugenics, a system or science concerned with improving races by breeding.

He was a contemporary of Charles Darwin (his cousin), of Thomas H. Huxley, Herbert Spencer, and of a number of other noted men—men whose insight and aid were valuable to him in developing his own ideas and his work.

More specifically, Galton was born under a most favorable and healthful environment, amidst green fields, with long-lived ancestors, intellectual and well-to-do parents, with four sisters and two brothers older than himself. A sister made it her duty to look after his early education. Formal education in school and college he bore badly, for there is repeated mention of ill-health. He instinctively sought the open-air life, which to him spelled health. He was able to bear great physical exertion and exposure, a trait of value to him in exploring expeditions and which he believed he inherited from his mother's side—just as he looked upon his tendency to bronchitis and asthma as an inheritance from his father's side. Euthenically considered, it appears, however, that he overlooked the fact that his great-grandfather was country-bred and reacted on removing to the city, just as his father reacted, and as he himself reacted; for he had stated that he could not bear close, warm, and carpeted rooms.

On his mother's side both his grandfather and great-grandfather had been physicians and his mother desired him to follow in their footsteps. This he was willing to do and he entered hospital work, but during his university studies his health failed. About the time he completed his medical education his father died, and being left with independent means he never became a practitioner. The family now broke up, and he himself took to traveling and became a noted explorer.

In his *Memories of My Life* he mentions getting married and the value of marrying into a good family, but there is no mention of any offspring. References indicate that he had much ill-health in London, and he became a bird of passage, leaving the city on the approach of the closed-door season for an open-air climate. His cousin, Charles Darwin, reacted even more acutely to city conditions and left the city entirely.

A centenary presents an opportunity to review a man's life and work, but unless an essayist is unusually well qualified he may hesitate to express any opinions—but he can at least voice his appreciation and admire the industry revealed by a long list of titles. A full bibliography appears in his autobiographic *Memories of My Life*, and reveals his various and successive activities. His chief works may be referred to briefly:

The *Narrative of an Explorer in Tropical Africa* (1853) brought him the gold medal of the Royal Geographical Society. Several papers

"Proc. 38th Meeting, 1922 (1923)."

and monographs relating to travels and geography followed. The *Art of Travel or Shifts and Contrivances in Wild Countries* appeared in 1855 and went through a number of revised editions. His attention was then turned to meteorology and he charted data on a large scale. From him we have the term anticyclone. He developed great proficiency in making charts, diagrams and graphs; by applying this knowledge to the study of anthropology he advanced it through statistical methods. He became interested in the subject of heredity, and in 1869 published *Hereditary Genius*—and formulated his ancestral law, that the two parents contribute one-half, the four grandparents together one-fourth, and so on.

A difficult problem is presented by the comparative worth or desirable qualifications of individuals and races. Galton believed that much could be accomplished through proper nurture. *English Men of Science, their Nature and Nurture,* appeared in 1874. At intervals and between larger works he employed himself with all sorts of seeming oddities, including the making of "Composite Portraits", on which he published in 1878. Then came his *Human Faculties,* for which he had collected a great mass of data. In this work he for the first time used his newly-coined term Eugenics.

Galton was a pioneer in neglected fields. He brought together a lot of material and from a careful study arrived at certain conclusions. Others have taken up his work and advanced it and presented it more systematically, but the name of Galton will always be associated with Eugenics.

A study of the lives and the books of the master minds enlarges our vision. Too many of us are controlled by our emotions—we may see only the need for immediate relief from misery and affliction. Few of us consider future generations nor the constant crop that calls for more and more relief. Great minds, as Galton's, are concerned with fundamental causes and with the diffusion of knowledge and prevention.

The measurement of physical and mental qualities was definitely taken up by Galton through the establishment of an anthropological laboratory. Today we hear much about psychological testing, a subject that was wholly new in 1884. The late war gave a great impetus to measurements, and at present school children, mainly in city schools, are tested from all angles—new and improved tests are constantly introduced. In *Natural Inheritance* he again advocated the breeding of desirable qualities and the checking of the undesirable. His observations on Finger Prints appeared in 1893; the practical value of this was soon recognized and developed.

In 1904 Galton founded a research fellowship at the London University for work in Eugenics, which has been a great stimulus to the whole world. In this connection attention may be called to the Galton Lecture of 1919 by Dean Inge of St. Paul's, which appears in his *Outspoken Essays.* This lecture is remarkable when we consider that it is by a noted churchman.

In England where life conditions for a long time have been fixed, static—"as the father so the son"—inheritance plays a great rôle; all in marked contrast to conditions in our own country. England, and the

old world generally, where there is no immigration problem, offers the best opportunities for the study of Eugenics. Our own country is in a constant flux, dynamic; there is no predicting the vocation or career of the son of even the humblest citizen. Uneducated parents may have ideals, and by giving the son a higher education may enable him to become a superior man. At present we do not realize how much talent is submerged, needing only suitable life conditions—a proper environment—to rise to the surface.

Galton's *Memories of My Life*, published in 1909, two years before his death, is a book well worth reading. From this autobiography we may again learn, that which stands out strongly in all his work,—that great minds are concerned with fundamental causes.

LIFE AND MIND.

Robert W. McBride, Indianapolis.

We live, and we think. What is life? What is that we call mind, of which thought is a product?

Science gives us no satisfactory answer to either query. The best it can do is to surmise, to speculate, and imagine; or, in other words, to guess; and some of the guesses seem to me extremely wide of the mark. While I am not learned in any department of science, I look with interest on the efforts of the real students of science to solve the riddle of the universe. But when the scientist reaches a point where he can only surmise, speculate, and imagine, I feel justified in making my own guess.

Modern science has opened for us wonderful vistas in every direction. It reaches out into space and tells us with certainty of suns so far away that light can only bridge the distance in more than a hundred thousand years. What this means can be appreciated, when we remember that light in eight minutes leaps across the ninety-three millions of miles that separate us from the sun. With equal certainty science delves into the depths of the infinitesimally small, until its discoveries stagger even imagination. It has made the earth's strata an open book, in which we read the story of the ages. It has harnessed the powers of earth and air and made them our servants. Wherever science leads us we find an apparently homogeneous universe, homogeneous in the sense that matter in the distant sun, as revealed by the spectroscope, does not differ from matter as we know it on this insignificant atom—our world, all apparently obeying uniform, unchanging, and unvarying laws that rule everywhere and everything, from the mighty sun as it wheels in distant space, to the tiniest animalcule revealed by the microscope. Such laws tell us unmistakably of an intelligence beyond our possible comprehension. While finite mind can only imagine infinity, we find in these things what seems to us infinity in space, infinity in duration, and infinity in that Power which lies back of and apparently originates that controlling law. That law is therefore the product of "Infinite Mind."

But with all its accomplishments, has science as yet succeeded in explaining any fundamental reality? Thus, the universe is composed of what we call matter. Science, explaining matter, long ago told us, with an air of absolute certainty, of ultimate atoms, the most minute particle into which matter could be divided, of molecules, and of many elementary substances. It now tells us that the atom is not the ultimate thing they once thought it, but that back of the atom lies the electron. It tells us that instead of the many elementary substances of which we were once assured, it is possible or it may be probable that there is only one single elementary substance, and that the so-called many elementary substances are simply due to the manner in which the electrons are arranged or grouped. The reasoning impresses us, but it comes to us with the frank admission that no one ever saw an electron.

"Proc. 38th Meeting, 1922 (1923)."

While time may prove that this theory is correct, I think it safe to say that the problem is not yet solved.

Again, I am bewildered when I am told about a conjectural, universal ether, that is supposed to fill all space, to be everywhere present—a something more dense than any known substance, and yet a something in which we freely move and in which the myriads of suns and planets revolve. Another one of science's guesses.

We ask science about that mysterious power that caused the falling apple to hit Newton's head and sent him conjecturing until he identified it with that power which rules the march of the worlds, and which we call gravitation. But when we ask what gravitation is, science answering only gives it a name and tells us something of the ways in which it acts. It cannot tell us what it is.

Among the many unsolved mysteries, is that of life. And here, again, science fails us. An article in the last edition of the Encyclopedia Britannica, which purports to tell us what life is, begins with the statement that life is

> "The popular name for the activity peculiar to protoplasm",

and follows with an inconclusive two pages that get nowhere, and does not even attempt any clearer definition or explanation.

The Encyclopedia Americana frankly says:

> "No definition of life has ever proved quite satisfactory."

It then quotes several definitions, including Herbert Spencer's amended conception of life, which I quote. It is, Spencer says,—

> "The definite combination of heterogeneous changes both simultaneous and successive in correspondences with external co-existence and sequences."

I quote this because of its lucidity and clarity. Quite as much so as a London fog.

None of these attempted definitions throws any light on what life really is. The writer of that article, after quoting several, says:

> "The most recent attempts have been in the direction of proving that life is merely a form of energy or motion."

This, I can begin to understand. True, Sir Oliver Lodge, who is universally recognized as one of the most eminent and learned of living scientists, tells us that life cannot be a form of energy. I quote from one of his latest published utterances. He says:

> "Life must be considered *sui generis*. It is not a form of energy, nor can it be expressed in terms of something else. Electricity is in the same predicament. It too cannot be explained in terms of something else. This is true of all fundamental forms of being. * * * To show that the living principle in a seed is not one of the forms of energy, it is sufficient to remember that the seed can give rise to innumerable descendants through countless generations without limit. There is nothing like a constant quantity of something to be shared as there is in all examples of energy.

> There is no conservation about it. The seed embodies a stimulating and organizing principle which appears to well from a limitless source."

He adds:

> "But although life is not energy any more than it is matter, yet it directs energy and thereby controls arrangements of matter."

Lodge here uses the term "energy" in the limited sense familiar to the physicist and defined by them as the power or capacity to work. Thus limited, he says life is not energy. This will also exclude gravitation and electricity from the list of modes of energy, for he admits that neither of them can be shown to conform to the laws governing the conservation of energy. I am a layman, and do not recognize this limitation as legitimate. To the layman, the word "energy" is one of the synonyms of the word "force." The Standard Dictionary defines the word "energy", among other things, as

> "The power by which anything acts effectively."

One of its definitions of the word "force" is, that it is

> "Any operating or operative *energy*; any active agency or power tending to change the state of matter."

Accepting these definitions as correct, it seems to me that gravitation, electricity, and life, are each and all forms of energy. It seems to me that gravitation, that power that holds the universe in its grasp, and electricity, as it lights our streets and homes and supplants steam in driving mighty engines, are certainly exhibiting forms or modes of energy.

To me, life is a force, one of the modes in which force manifests, for I believe that science is on the way to the demonstration of the unity of the so-called forces, as it has already practically demonstrated the unity of matter. That is, that as all the various so-called elementary substances are resolvable into one primeval form of matter, so all the various so-called forces are only various ways or modes in which one single force manifests itself. Life is the building or constructing and conserving force in nature. Sir Oliver Lodge says "it directs energy and thereby controls arrangements of matter." To me, instead of *directing* matter, it *uses* matter to build organic structures under the direction of that Infinite Intelligence which lies back of the laws which govern the universe. Instead of life directing matter, it is itself directed and the evidence shows that it slavishly follows the directions given it. To say that life directs, is to attribute to it intelligence. I can conceive of nothing in the action of life that indicates the possession by it of independent intelligence. The definition of life in the Encyclopedia Britannica, that "life is the popular name for the activity of protoplasm," seems to me flippant and unworthy of that great publication. True, protoplasm is the physical basis of life, that is, it is the vehicle or instrument by which and through which life's work is done. Protoplasm is not life nor is life protoplasm. Protoplasm, like other substances, may and does die, and dead protoplasm, like any other dead

substance, will decay or dissolve into the various substances which enter into its composition. Life is that which animates all things, from the animalcule or the bacterium to man, and it does its work by the exercise of force. Life drives that wonderful organ, the heart. It selects from the food the substances it needs, puts them in place, and casts off the residue. It drives the sap through the tree or plant, and unfolds the leaf or flower. Until stayed by death it is acting, and its action is force. The life which builds the tree, or paints the flower, does not differ from that which builds the man. Life is not an originator or a planner. It builds the various structures of organic life, but in so doing it simply follows the plans that are given it. The germs with which it begins its work in building a structure, are its trestleboards on which it finds the plans of that which it is to build. No microscope or other instrument devised by man can examine one of those germs and tell what it enfolds. That mysterious Intelligence that lies back of the great law is the architect that draws the plans, and life as it takes up its work with a given germ follows that plan without deviation, except as it may be interfered with by outside influences. An ovum and a spermatozoan encounter each other, they combine, and the stage is set and the actors are present for the drama of life. Life only waits for the proper and necessary conditions in the environment for the play to begin. Science may exert all its powers, but it cannot discover from that tiny germ what the production will be, but given proper conditions life begins its work, and in that little cell it reads the plans and specifications for the structure it is to build. With favoring conditions and no outside interference, it follows those plans without deviaton. It may develop and improve but it never originates. Life is a master builder, and a master preserver, for its work does not end with the building of the structure, it continues to preserve it. But where should we look for the architect,—the originator of those plans and specifications? Where, indeed, save in that Infinite Mind which lies back of the great law that rules the universe.

The conduct of mankind is regulated in accordance with the evidence of our senses, and, unless we reject all of the evidence thus furnished us, mind is only another name for the Infinite Intelligence that pervades the universe, and is also the directing power through which man exercises control over material things. True, the materialists tell us that mind has no existence save as a function of the body, or of one of the body's organs, and that thought is a mere secretion of the brain. Cabanis, a distinguished French physician, expressed the idea in this way. He said:

> "The brain is determined to thought, as the stomach is to digestion, or the liver to the secretion of bile."

The German, Voght, expressed the same idea in the following language:

> "Thought stands in the same relation to the brain, as the bile to the liver, or the urine to the kidneys."

Buchner, another German, says:

> "Mind, like light, heat, electricity, or magnetism, is a movement of matter."

The late Ernest Haeckel, the famous German materialistic biologist, in his book "The Riddle of the Universe," says that neither mind nor soul have any origin, because sensation is an inherent property of all substance, and that conscious soul is a mere function of the brain. It is worth something that these gentlemen recognize that mind has an actual existence, even if they do degrade it to a mere function of one of the bodily organs. In animal physiology, a function of an organ of the body is simply its normal mode of action, and therefore necessarily involuntary and automatic. The bodily organs all have their functions. The heart, the lungs, the stomach, the liver, and the kidneys, have each their functions or their normal mode of action; and none of them can voluntarily refuse to act or change the manner of its acting. They act automatically. The action of the mind, therefore, according to these men, is simply the normal automatic action of the brain, as digestion is the normal and automatic action of the stomach. In animal physiology, a secretion is a substance existing in the blood, which is prepared and separated therefrom by glandular activity or by the action of the epithelial cells, as milk is separated from the blood and secreted by the mammary glands. To follow their argument to its legitimate conclusion, we might say that as all the organs of the body are built from the food we eat, and perform their functions by the power thus generated, and as all the bodily organs are produced from that same food, mind and thought really originate in the stomach, and that organ is the abiding place of the soul.

According to these learned gentlemen, therefore, the mind is a mere function of one of the organs of our body, as digestion is a function of another. Our much vaunted thinking and reasoning is only a secretion that oozes from our brain, as the tears ooze from our lachrymal glands while we weep over the dismal hopelessness and purposelessness of human existence as thus pictured by these scientists; and their erudite productions are no more than material exudations from their material brains.

The works of these materialistic writers, showing as they do that they are the result of much study, are alone sufficient to refute their conclusion. This is particularly true of the work of Haeckel. His work is not the production of a mere automaton. When we read the record he made of his lifetime studies in the field of biology, we know that it is not a record of the mere involuntary working of a bodily function. Every page evidences purpose and design; an individual and personal purpose and design that could not possibly find its origin in a mere bodily function. The existence of this purpose and this design is as obvious in that work as is the existence of purpose and design in the work of the Infinite Intelligence that is over all. The immediate and impelling power by which the various bodily functions perform their several offices, is life,—that force which builds the body. But life only follows the plan it finds in the germ with which its work begins. It

never changes that plan, or makes the mistake of developing the human germ into some other type of animal. Every function of the body is potentially present in the germinal dot from which the body grows. The various secretions of the different bodily organs are also automatically produced and their normal character is potentially determined when life begins its work with that germinal dot. The liver cannot secrete tears, nor can the lachrymal glands secrete bile. Whatever there is of purpose or of design that determines the character of these secretions, must be sought in the work of that Infinite Intelligence which lies back of the germinal dot. If thought is nothing but a secretion of the brain, we can no more originate and direct that secretion than we can originate and direct the secretions of other organs; there can be no such thing as an intention of thought, and our so-called reasoning is a mere involuntary discharge of an involuntary secretion, as free from inherent intention, or from voluntary and independent purpose, as is the urine or the bile. They tell us that the beginning of all organic life was in a germ or germs that in some way appeared in primordial slime. They also tell us that these germs have developed throughout countless ages into myriad forms of life, and that among these forms they find the physical man of today. They may be right as to this, for physical man is still "of the earth earthy", and can hardly deny kinship with the slime. Keeping their eyes on that slime of the distant past, and on the life force that stirred its depths when that germ appeared, they seek only in the dust of the ages and in that life force for the origin of all the qualities they find in the man of today. They might as well attribute the secret of Canova's genius to the marble of Carrara, or the inspiration of Michael Angelo or Raphael to the pigments they used. They remind one of Bunyan's "Man with the Muckrake". If they will but lift their eyes from the dust and study the harmonious rule of that power which governs the universe, they will find the source of the crowning glory of humanity.

> "The Heavens declare the glory of God, and the firmament showeth his handiwork. Day unto day uttereth speech, and night unto night showeth knowledge. There is no speech nor language where their voice is not heard."

As the mysterious thing we call "magnetism" may enter into the apparently inert needle of steel and give to it a new quality or power, and as magnetism's mysterious relative, electricity, when it is sent coursing through a wire, imparts to the filament in the bulb the power to emit light, so man, at some point in the course of his development, has had imparted to him a power beyond anything that can originate in that form of force we know as life. Life acts automatically, but this new power enables man to originate action,—to think, to reason, to decide, and to do. Common sense is a most excellent possession, and common sense would dictate that in searching for the origin of mind we should look where we know mind to be. One would not search for tropical flowers at the north pole, nor for icebergs at the equator.

In conclusion, my guess, as above indicated, is that life is the constructing and conserving force in nature, and that mind in man, in-

stead of being a mere exudation from a material brain, is that Infinite Mind itself shining through the clouds of matter, and gradually developing the brain as an instrument for its future use; that the limitations of our mental processes are due to imperfections in the instrument it uses, an instrument not yet fully developed. Imperfect as its manifestations are, I see in it that which thinks, which reasons, which plans, and which directs; that which inspires and lifts; that which creates the beautiful and majestic things the artist and the poet embalm in color and in words; that which makes great men, great leaders of men, great statesmen; that which makes men great in anything; that which reaches out into space, further than the most distant suns of which science tells us,—further, still further, until we feel there is no boundary in space; that which looks back through the record of the ages gone,—backward and still backward, until time disappears, and we feel there is neither beginning nor ending, only an eternal now; that by which we grasp the immensity, the majesty, the beauty, and the symmetry, of all, and which forces upon us the conviction, not that there is *a* God, but that God is.

ESTIMATING THE COMPARATIVE RICHNESS OF INDIANA.

Stephen Sargent Visher, Indiana University.

It is difficult to evaluate the many items which together make up the richness of a state, and hence carefully considered comparisons of the comparative wealth of large areas, as states, are few or lacking, although poorly founded assertions of superiority are common.

In spite of the great difficulty of arriving at a just statement of the richness of a state like Indiana it is very desirable that the citizens have a well founded idea as to the standing of their state.

My studies have convinced me that Indiana is one of the most fortunate areas in America. I doubt if another area of like size is permanently richer, except an area which would include a large part of Indiana. But what existing state is richer in proportion to size? Iowa is perhaps a better farming state, but she lacks many of Indiana's advantages. Illinois has Chicago, and more coal than Indiana but she is likewise much larger and has numerous difficulties and responsibilities which Indiana has to a lesser degree. Ohio, another fortunate state is inferior to Indiana in having a wide lake and a national boundary largely shutting her off from the north, a less central location and a larger percentage of rough land.

Indiana has a far smaller coal reserve than several states, but in the long run coal is less important than climate, topography, soil and a favorable location. Some believe that accompanying the practical exhaustion of coal, there will be an altogether different distribution of the industrial centers. For example, that the more important parts of our nation will then be near the Cascade Mountains because of the great water power resources there. However, I suspect that instead power will be brought to the places which have a favorable climate, fertile land, and already well established industries.

But now to consider how Indiana compares at present with other states. Indiana is 37th among the states in point of size. She is surpassed by many larger states when totals are concerned, but totals are often less significant than amounts in proportion to population or in proportion to area, or in proportion to needs.

The gross value of farm products affords one excellent basis for comparison between the states. In this respect, Indiana ranked eighth in 1919[1]. However, only three states ranked ahead of Indiana in the value of farm products in comparison to size. Iowa, the leader in 1919, produced only ten per cent more while Ohio produced only a trifle more per square mile than did Indiana.

The "gross value of farm products" is made up of crops, livestock products and animals sold or slaughtered. In respect to value of crops, although Indiana ranked thirteenth state in 1919, when allowance is made for comparative size, Indiana is seen to surpass all but Iowa, Illinois and Ohio. In livestock products, Indiana ranked eleventh but six

[1] Statistics given are all official census figures.

"Proc. 38th Meeting, 1922 (1923)."

of ten states ahead of Indiana are enough larger to fall behind Indiana when comparative area is considered. Indiana stands still higher in the value of animals sold or slaughtered, ranking seventh when size is ignored, but claiming third place when area is considered.

In respect to individual crops: Though often surpassed by five states, Indiana ranks with Illinois and Iowa as a corn state, when area is considered. Indeed, in average yield of corn per square mile, Indiana surpasses these states, as well as the other three—Missouri, Nebraska and Kansas, which often have more acres planted to corn than Indiana. In wheat production Indiana normally ranks eighth, but is usually exceeded only by North Dakota and Kansas in the average yield per square mile of total area. In oats production, Indiana ranks seventh, but fourth when area is considered.

Indiana is second in hog production, and in eggs; third in the average crop yield per acre during the poorest years; third in the average value per acre of farm land, and in the percentage of improved farms; third in poultry; and sixth in the dependability of crop yields from year to year. The only states which surpass Indiana in this very important respect are in the extreme East, on the Atlantic Coast.

Few people realize how large a total income is obtained from Indiana's forest trees. In 1919, Indiana marketed eleven million dollars worth of forest products, ranking nineteenth among the states. In proportion to area, however, Indiana ranked thirteenth.

The value added by manufacture (724 million dollars) was only a little less than the gross value of farm products, which was 782 million dollars in 1919. As a manufacturing state, Indiana ranked ninth among all the states in 1919. Indiana had more than two dozen manufacturers, yielding products worth over ten million dollars in 1919. The leading industries of Indiana according to the Census are: 1. Steel, forgings, etc., producing products worth 192 million dollars and giving Indiana third place among the states. 2. The Indiana products of the automobile industry had a value of 179 million dollars in 1919 and Indiana was surpassed only by Michigan in this respect. 3. The third industry in value of products, was the manufacture and repair of railroad cars, etc. The total for 1919 was 149 million dollars, and Indiana's rank was about fifth. Indiana ranked ninth in the value of the slaughtering and meat packing industry, with a value of 134 million dollars. However, if comparative area is considered, Indiana would surpass half of the eight states which have greater totals. Indiana ranked third in the production of agricultural implements in 1919. In the value of products of the canning industry, Indiana should take fourth place instead of sixth. Likewise, although Indiana was about eighth in the value of the products of flour mills and grist mills, she is enough smaller than the higher ranking states to surpass all but the leading state, Minnesota, in value per area.

In mineral products also, Indiana ranks high, second in the production of cement, fifth or sixth in coal, fourth in coke, fifth in brick and tile.

In brief, in spite of her comparatively small size, the 37th state in

this respect, Indiana ranks second in the automobile industry, in cement, and in flour and grist mill products, third in the steel industry, in corn and wheat production, and in animals sold or killed; fourth in the gross value of farm products, of crops, of livestock, of oats and of coke, and in the canning industry; fifth in meat packing and in coal mining; eighth in manufacturing; and thirteenth in forest products.

Conclusion: Indiana's high rank in these diverse but fundamental respects indicates clearly that our state is very rich. No other state is notably richer, in proportion to size and population. Although a few other states are richer in total wealth, they also have a larger population to serve and a larger area to cover. Furthermore, their sources of income are not so diverse as are Indiana's nor are the yields of their crops so dependable year in and year out.

Indiana's wealth is not of the short-lived kind; most of the state has very deep, fertile soil; the climate is excellent in many ways; and Indiana's central position is very advantageous. We need not be surpassed by Michigan, Wisconsin, or any other less well endowed state. We should lead.

THE SOUTHERN UTE INDIANS OF PINE RIVER VALLEY, COLORADO.

ALBERT B. REAGAN, Cornfields, Ganado, Arizona.

The Southern Ute Indians of Pine River Valley, Colorado, are the Moache and Capote divisions of the great Ute family. They were once very numerous and occupied portions of Utah, Colorado, and New Mexico, and possibly even a portion of Arizona, for in 1775 Father Escalante visited them in the region north of the Hopi villages in Arizona. They now number only 352.

Since 1863 they have occupied their present reserve and are now making rapid strides toward civilization, though they were slow in making the start. Today they live in modern houses and every family has its little farm on which grain, corn, fruit and garden truck are raised. They have done so well in recent years that in the Dry Farming Congress at El Paso in 1916, they carried off the Silver Cup Prize in competition with all the other Indians in the United States.

They still practice a few ceremonies and perform a few dances. Among the latter is the "Bear Dance", so-called because the Utes assert that the bear originated the ceremony in the long ago. It is performed in the early spring or the first days of summer and usually lasts four days. It is a big event and the Apaches, Navajos, Mexicans, and whites join with the Utes and all have an enjoyable time. Below is a description of one of these dances as given near Ignacio, Colorado, in June, 1917.

Preparatory to the dance, a level plot of ground was selected in a pasture near town, and a dancing field some 300 yards in diameter was laid off and inclosed in an artificial, upright hedge fence. Benches were placed within the inclosure along the northwest half of the fence for the men to sit on, the ground within the inclosure along the southeast sector being reserved for the women to squat. Within the inclosure on the west side a deep hole was dug over which an inverted tub was placed. This was then inclosed in a square-bench enclosure on which the musicians were to sit. Heavy oak sticks, two and one-half feet in length were notched in "washboard style"; some also had carved heads with eyes and mouth for the sounding end of the stick. Bones of suitable length and thickness were also secured for the rubbing process in the "music-making".

The dance was given only of afternoons until the fourth day when it lasted the whole day, followed by a feast.

When all was ready, the musicians, seven in number, seated themselves on the benches around the tub-drum and leaning their notched sticks so as to place the end farthest from them on the inverted tub-bottom with notches up, they began to sing a chant in the minor key. As soon as the song "had warmed up to a sufficient pitch", the musicians began to keep time by rubbing the bones up and down over the notched sticks producing a reinforced, ear-grating sound.

"Proc. 38th Meeting, 1922 (1923)."

After the first song, a speech-prayer service was conducted by the chief of ceremonies. Then the women chose male partners by approaching and waving their hands toward the one of their choice. If a white man was chosen he was expected to pay for the privilege of dancing, and any one chosen was obliged to accept or get out of the enclosure. Preparatory to the dance the men and women lined up facing each other in column abreast, the women in one column, the men in the other. The members of each column held hands, one column taking two steps forward and the other two steps backward to the time of the music, then *vice versa*. Thus was the dancing kept up in a set and continued in each succeeding set till the closing dance the fourth day, the Indian women choosing a new partner for each set.

The closing set was an endurance test. It began the same as the others, but soon changed to a single couple's partner dance in which the partners held each other in a position similar to that taken in our waltzes; the step, however, was the same as before. This dance was kept up till the participants quit of exhaustion. One participant fell down in the dance and the medicine man used one of the drum sticks as a wand and collected the evil spirits on it and then sent them to the four winds; he laid the stick first on her feet, then across her hips, then across her breast, then across her back, and lastly on her head. Unless this was done, it was believed some misfortune would befall her.

After the close of the endurance fête, the chief medicine man took a cup and as he danced, he held it upward as an offering of thanks to the gods and as a prayer for rain. His dance was followed by two speeches by two leading men. Then a feast was set out for all, after which they returned to their respective homes, believing that the gods would bless them and give them a bountiful crop.

An interesting account of the habits of the Southern Ute Indians is given by Dr. Alex Hrdlika in bulletin 2, part 2, pp. 619-620, of the Bureau of American Ethnology.

TWINKLING STAR.[1]

ALBERT B. REAGAN, Cornfields, Ganado, Arizona.

Synopsis.

The Apache medicine girl Twinkling Star is dying of consumption. Medicine singings are held over her night after night. The magic, medicinal powers of the snake, frog, medicine god, medicine stick, and medicine cane are applied, but she gradually declines. The medicine game is then played to make her well, but the medicine man loses the game. The Gunelpieya Medicine Disk ceremonies are resorted to, and these are followed by the medicine dance. In the excitement, at the climax of this performance, Twinkling Star joins in the dance in hilarious action. She swoons and dies. A wild, indescribable scene follows. After the body is elaborately attired, it is carried to the mountain side and buried with her personal effects under a piñon tree. Her live stock is then killed and her tepee burned. This being done, the women wail and mourn for her at morning, noon and night for thirty days.

Characters.

1. Twinkling Star and the people about her tepee.
2. Chief Medicine Man F-4.
3. Medicine singers.
4. Gumwapah, an old medicine woman.
5. Clowns and ghost dancers and other medicine actors in the Gunelpieya Medicine Disk ceremonies.
6. Medicine dancers and assembled Indians.
7. Actors in the ceremonies over the dead.

Scenario.

Scene 1.—Twinkling Star, a young Indian woman, sits in front of her father's tepee coughing and showing every symptom of a person in the last stages of consumption.

Scene 2.—Subtitle: "Medicine Singing Performance."

Night comes on and the medicine people come to her tepee to perform over her. Among them is Chief Medicine Man F-4.

Scene 3.—The sick one reclines on a pine-twig mat by the fire within the tepee.

Scene 4. The medicine man enters, goes over to the side of the tepee by the central fire and doubles his feet under him in a sitting position near the sick one. He then bends his body over forward, places his hands claspingly over his face and forehead in the form of a sort of hood and begins to sing.

"Go away sick! Go away sick! Go away sick!"

[1] This scenario depicts the medical attention given Twinkling Star, an Apache girl, the death scene and burial ceremonies, as acted out by the Indians and witnessed by the author, in 1902.

Scene 5.—The musicians enter and begin to beat tom-toms (pots with rawhide stretched over their open faces).

Scene 6.—The medicine man stops singing, spits in the fire, and sprinkles the sick one with cattail flag pollen. He then resumes his singing with posture as before.

Scene 7.—The medicine man produces a crudely made, striped, wooden snake. This he places in the hot ashes a moment. He then places its head on the afflicted parts of the bared body of the patient in four different directions, corresponding to the semi-cardinal directions. As he thus places it, he sings and points respectively to the gods who are holding up the four corners of the earth. He then burns the wooden snake, as he sends the evil spirits away with a hissing breath and looks with elevated face toward the northeastern heavens.

Scene 8.—The medicine man produces a wooden frog and performs with it same as he had performed with the snake in 7.

Scene 9.—The medicine man resumes his singing with posture as in scene 3.

Scene 10.—The medicine man produces a wooden carving, an effigy of his leading medicine god (fig. 1). This he places on the sick woman as he did the snake in Scene 7.

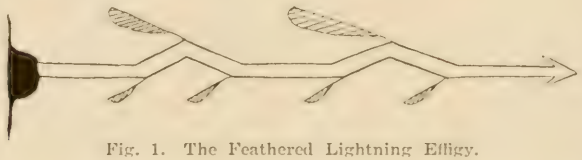

Fig. 1. The Feathered Lightning Effigy.

Scene 11.—He hides the medicine god in a niche in the rocks of a neighboring cliff.

Scene 12.—The sun comes up and the ceremonies cease. But the patient is worse.

Scene 13.—Night brings the medicine man and the musicians to doctor the sick one again.

Scene 14.—The medicine man sings over the sick one; the musicians beat the tom-toms.

Scene 15.—The medicine man performs over the sick one with five medicine hoops some two feet in diameter and colored to represent the colors of the rainbow, performing the same as he did with the snake in Scene 7.

Scene 16.—He then takes the hoops and hides them in a niche in the rocks on a nearby mountain side.

Scene 17.—He performs over the sick one with medicine stick (fig. 2) as with the snake in Scene 7 and then burns it.

Scene 18.—He performs over the sick one with a medicine cane as with the snake in Scene 7. He afterwards buries the cane in the floor of the tepee.

Scene 19.—Subtitle: "The Medicine Game."

He plays the medicine game (fig. 3) with four flat splints with a chosen partner. The sticks are bounced on a flat rock in the center of

a six foot circle of forty cobble-stones. The sticks falling with a certain side up are favorable to the recovery of the patient. Knowing that the patient will die, the medicine man plays to lose the game.

Insert: "The sick one grows steadily worse day by day."

Fig. 2. The Medicine Staff, with dangling medicine pouches.

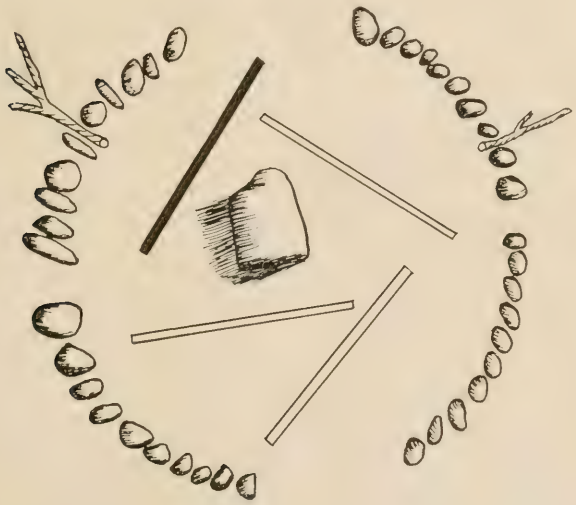

Fig. 3. Game Field of the Medicine Game, showing the "cobble-stone circle" and counting sticks in place showing the counts received (they are the sticks lying between the cobble-stones). The two wide spaces are designated "water". Should the tallies be such as to place a tally-stick in either of these spaces, the player loses all the points he has made in that game-count and, consequently, must begin the count again. The game sticks, as they have fallen within the circle in the cut, count the thrower two points. One hundred and sixty-four continuous points constitute a game.

Scene 20.—Subtitle: "The Gunelpieya Medicine Disk Ceremonies."

A horseman rides swiftly up the valley and summons the people to make a medicine disk (fig. 4).

Scene 21.—In the mid-forenoon the people assemble in a protected spot at the edge of the woods and proceed to make the likeness of the "Sun Father" on the ground in disk form, in accordance with the Indian belief. The drawing is some sixteen feet in diameter. It is the front view of the massive head, with a crown for a hat and the suspended "medicine squares" for a necktie. There is no nose, or neck, or body shown. The eyes and eyebrows are there as is the mouth. The latter is peculiar. The lips are in the form of a square set naturally with the face. They are parted showing the odd-shaped mouth. This is shaped like a diamond, or square, so drawn that each of its respective corners bisects a side of the square that forms the lips. From the mouth at

Fig. 4. A Medicine Disk, used at another, but similar, medicine performance.

the left there is supported a long stemmed pipe, on which is drawn the bolt lightning. And from each corner of the lips, as drawn, a funnel-shaped wisp of the sun's rays extends out into measureless space. The different parts of the drawing are variously colored in red, white, black, gray and green. The red coloring matter is made from ground up red sandstone; the white from ground up limestone; the green from crushed leaves; the black from pulverized charcoal; and the gray from a mixture of charcoal and limestone.

Scene 22.—The disk being completed, a canvas is stretched around it leaving a small doorway at the east side.

Scene 23.—Insert: "The sick one is to be presented to the drawing of the god of day; and he can either cure her or take her to his abode in the immensity beyond."

The actors come. Gumwapah, an old medicine woman carrying a dirty bowl partly filled with water, comes from a near-by wigwam; enters the medicine disk by way of the pipe stem; and, in a stooping position, passes around within it from left to right near its outer rim. As she thus moves around near the drawing of the outer circle of light, she takes a pinch of the coloring matter from each respective part of the drawing and puts it into the cup. Completing the dust gathering, she sets the bowl down in the upper corner of the sun's mouth and then passes out of the disk drawing by the way she came.

Scene 24.—The medicine men come with the patient from a near-by tepee. They are carrying her. They also enter the disk by the pipe stem. They carry her around the circle of the sun's rays from right to left; then to the center of the sun's mouth and place her upon it with face turned toward the afternoon sun.

Scene 25.—A medicine ghost dancer sallies forth into the open space from a nearby thicket. He is nude with the exception of a dancing skirt. His body is painted in white, and zigzag lines run up his arms and down his lower extremities to represent the blazing thunder bolt of the raging storm. He also wears a loose, sack-like cloth mask, on top of which there extends skyward a row of lath facing the front and so placed as to crudely represent the spread tail of a turkey. In addition, he carries a sword-like wand-stick in one hand and an old Indian knife in the other. Shrieking, whooping, and occasionally gobbling like a turkey, he crow-hops in a large circle around the drawing of the god of day and the sick one waiting to be cured, posing now and then in baboon style. Completing the circle, he makes a rush sidewise for the presence of the sick one like a male swine going to battle. Reaching her presence, he squats in front of her, sticks the knife in the ground by her side, places the wand on the afflicted parts of the sick one in each of the semi-cardinal directions, gathers the sick on the wand in this way, takes the wand up before his face, blows a hissing breath on it to drive the evil spirit "sick" away. He then gives a hideous, ear-grating howl, seizes his knife and gallops forth into obscurity.

Scene 26.—The chief medicine man enters the circle, and, taking a piece of green gourd rind in his hand, he rubs the sick one all over with it. He then daubs her all over with the muddied water from the bowl, the moistened dust of the drawing of the Father of the Day. This being completed, he places the gourd rind against the lower end of the sick one's breast bone and sings a song to the gods to help her, the musicians with tom-toms aiding him in the singing.

Scene 27.—The sick one is carried from the medicine disk inclosure; and the medicine drawing is at once obliterated.

Scene 28.—Subtitle: "The Medicine Dance."

A huge fire is kindled in the center of a level area among the hills. Here are assembled all the people of the valley. Around the fire in a great circle they are squatted on deer skins. At one end and within the circle are the doctors and musicians; but the dancers and sick one have not yet arrived.

Scene 29.—We find the sick one in a near-by improvised tepee. She is lying face down on a mat and medicine women are rubbing her back with scorching, smoking piñon twigs. Time and again she faints, only to have the twigs snatched from the blaze quicker and applied to her back. But the dancers are coming.

Scene 30.—The sick one is carried to within the circle of human beings and placed on the opposite side of the fire from that occupied by the musicians.

Scene 31.—The tom-toms begin to beat. The chief medicine man leans his body forward and covers his face with his hands, holding them in a sort of hooded position. The doctor and the musicians commence the monotonous chant, as they wave their bodies to the time of the music. The sick one looks expectant. They are coming, the ghost dancers of the gods. They enter the circle of light from the northeast. There are five of them. Four of them are attired as was the dancer in the afternoon (Scene 25); but now each carries a wand in either hand. The fifth actor is a clown. He is attired only in breech-cloth and is masked with a horned mask. He carries a wand in his left hand, a three-pronged stick in his right. Around the central fire, the musicians and the sick one, they dance in single file for a considerable time, the four dancers posing now and then and gobbling the while like a turkey, which they are supposed to represent; the clown at times cuts capers and tumbles around over the ground to amuse the populace.

At last they approach the sick one in single file. Then acting like a bird when it has seen something it is rather afraid of, they gobble and dance backwards from her presence in single file. Again and again they approach her, each time getting a little closer to her. Finally the foremost dancer of the line leaves his fellows, trembling, prancing, and dances to the feet of the patient. She sits up. He leans over her. He places his wands crossed on her head, on her back, on her lower extremities, and on her chest. Then he raises the still crossed wands toward the northeastern heavens and, as he parts them with a sweeping motion and emits a hissing breath from his mouth, he scatters the "sick" toward the four winds. And with a shrieking howl, he canters off into the blackest darkness.

The rest of the dancers follow in succession and perform in a similar manner, as does the clown also, except that he acts the clown as well as a medicine dancer. His principal feat is to kill the "sick" by spearing it with his trident after he has collected it on his wand. His performing completes the first of this setting. There are three more scenes in it, all of which are similar to the one just described, except that in scene two the sick one faces the southeast and the actors approach her from that region; in scene three the sick one faces the southwest, and the dancers the northeast; and in the fourth scene she faces the northwest, the actors the southeast. But they are gone and another set of actors are taking their places.

Insert: "Throughout the night dance ceremonies like the above are kept up till thirteen consecutive dance scenes are completed. Then comes the closing scene."

Scene 32.—As the sun begins to show his advance fingers of gorgeous colored light over the eastern mountain peaks, the clown wakes all the sleepers with his trident and compels them to stand up. The chief medicine people sprinkle all with sacred meal. Every one takes one more drink of Indian whiskey (twiswin). The medicine dancers approach the sick one again. As they perform, every one joins in a straight backward and forward dance within the circumscribed area. The excitement becomes intense. They all shriek and shout till the hills re-echo it again and again; and the drummers pound the tom-toms till it seems as if the very poles of the earth have thundered. The sick one makes one supreme effort to rise and join in the dance but she has not sufficient strength. They lift her to a standing position, they sprinkle her with the sacred dust, they rub her back and her chest with scorching fir twigs, they support her in a dancing position. She makes one more heroic effort to dance and become well. Greater and greater becomes the excitement. The chief medicine man prays louder, the shrieks and shouts of the dancers become deafening. The crisis comes. In the excitement, under the influence of the hypnotic spell, the sick one forgets her ailments. She dances. She takes a medicine hoop in each hand. She lifts them high above her head. She leaps. She crow-hops. She poses. She struts around the great fire like a turkey. She calls the gods by name. She shrieks, swoons and dies.

Scene 33.—Subtitle: "The Ceremonies over the Deceased."

Words can not describe the scene that follows. The men weep, the women wail with the hideous coyote yelping wail. They pull their hair out by handfuls, then rend their apparel and destroy their property at hand. They make a rush to see the corpse. They trample over each other, and it is with difficulty that they are kept from crowding one another into the great fire.

Scene 34.—They carry her to the nearest wigwam; strip, wash, and dress her; bead her with all the beads of the clan; put wristlets upon wristlets on her wrists; and roll her in her best robe.

Scene 35.—They take her and all her personal belongings to the mountain side and bury them beneath a piñon tree.

Scene 36. They then return to the village and destroy everything which belonged to her, both animate and inanimate, together with her tepee (the horses, cattle, dogs, were stabbed to death; the other property was piled up and burned).

Insert: "The property of the deceased is destroyed that it may be with her in spirit in the land of bliss."

Scene 37.—Subtitle: "For thirty days the women mourn and wail for the dead."

Then for thirty days the women go to some secluded place and wail and mourn for Twinkling Star at morning, noon, and night.

HISTORY OF THE LAKES NEAR LAPORTE, INDIANA.

W. M. Tucker, Indiana University.

In October, 1921, the writer's attention was called to the recession of the lake level in the vicinity of LaPorte, Indiana, by an appeal from the Park Board of LaPorte to the State Conservation Commission for suggestions as to the cause of the recession and means of raising the lake level. Since that time I have spent about three weeks in the field about LaPorte and have found a peculiar and very interesting problem. On my first visit to LaPorte I was accompanied by Prof. Will Scott of the Zoölogy Department of Indiana University and on my third and last visit I was assisted by Mr. W. A. Thomas, a student of Geology at Indiana University. I wish to acknowledge the services and suggestions of these men and also Mr. Maurice Fox, President of the Park Board of LaPorte; Dr. W. N. Logan, State Geologist; Mr. Burtis Thomas, City Engineer of LaPorte; Mr. Robert Day, Assistant City Engineer; Mr. W. A. Cummings, Park Superintendent of LaPorte; Messrs. J. W. and Archie Good, well drillers of LaPorte and many others whose suggestions and services were of value.

PHYSIOGRAPHY AND GEOLOGY OF LAPORTE COUNTY.

The physiographic conditions of LaPorte County are dominated by the influence of the Wisconsin glaciation. Mantle rock derived from glaciation overlie the Devonian limestones and shales to a depth of 100 to 250 feet or more. There are no bed rock exposures in LaPorte County. By reference to figure 1, the type of surface rock are evident. The southeastern 60.1 per cent of the county is an old lake flat. It is now called the Kankakee valley or Kankakee lowland. This region slopes gently toward the south from an elevation of somewhat less than 800 feet on the north to the Kankakee River somewhat above 700 feet on the south. The average slope of this region is about five feet per mile. Gravels and sands on the north merge into finer sands, clays and peat on the south. Great areas along the Kankakee were covered by swamp until recent drainage projects have reduced them materially. Considerable swamp land still prevails, however.

Lying northwest of this lake flat is the great Valparaiso moraine. This area comprises 29.6 per cent of the county. The crest of this moraine is represented in general by the divide on figure 1 and that part lying north and west of LaPorte is shown accurately. This crest is undulating reaching elevations about 950 feet and seldom reaching lower elevations than 900 feet. The south margin of the moraine has an elevation of about 800 feet, usually slightly less. The north margin has an elevation of from 650 to 680 feet. Thus the north slope is much steeper than the south slope. The surface of this moraine is of the knob and basin character typical of well developed morainic regions. The north slope is undergoing severe stream erosion where the tributaries

"Proc. 38th Meeting, 1922 (1923)."

of Trail Creek have invaded it. The south side has a few small streams which empty into swamps or small lakes but the tributaries to the Kankakee have not invaded this morainal area. The Little

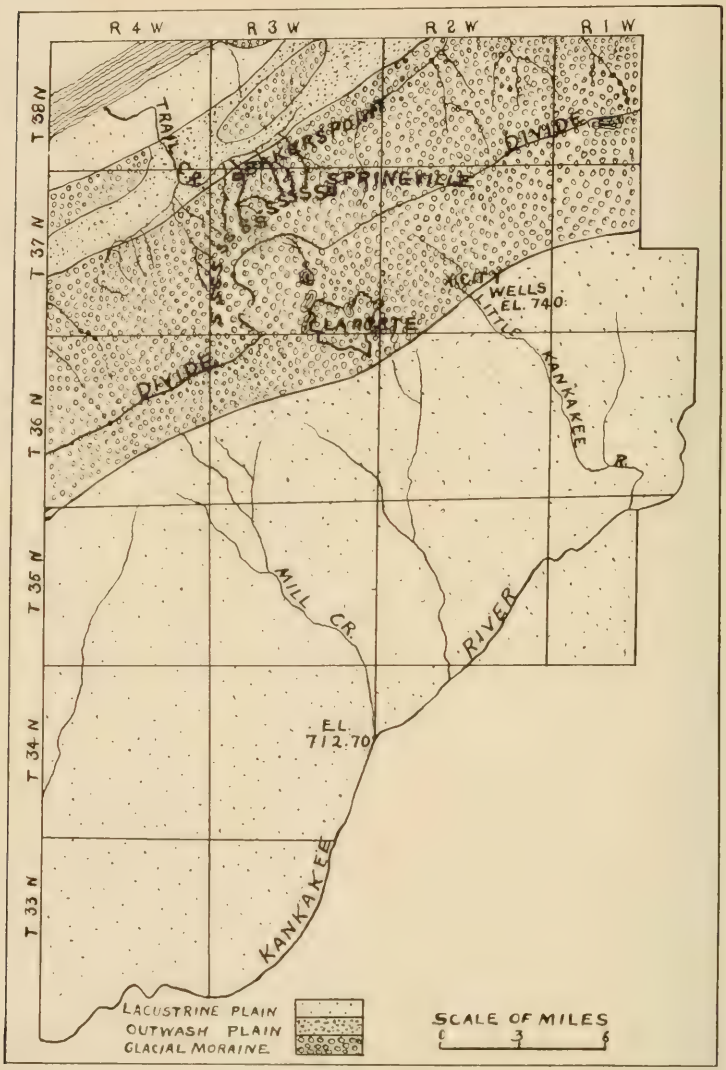

Fig. 1. Map of LaPorte County, Indiana, showing glacial deposits and other data. (After Leverett.)

Kankakee, east of LaPorte, is an exception to this rule. It rises in a glacial stream valley which lies within the moraine. The moraine is composed of sand and gravel with occasional lenses of clay. According

Fig. 2. Map of Laporte, Indiana, and surrounding territory, showing hydrographic features.

to Mr. Leverett[1] this moraine is predominately clay west of Valparaiso and sand and gravel east of that point.

Four other small areas lie to the northwest of the Valparaiso moraine in LaPorte County. These are a belt of outwash about two miles wide comprising 3.9 per cent of the county, small patches of moraine comprising 1.8 per cent, a lacustrine plain, part of the bed of Lake Chicago comprising 2.8 per cent and a part of Lake Michigan comprising 1.8 per cent. Sand dunes have encroached upon much of the land portions of these areas. Since these areas have little to do with the problem of the LaPorte lakes they will not be discussed in detail.

Origin of Lakes. Three types of lakes occur in LaPorte County. Those which lie in the Kankakee lowland are remnants of the great marginal lake which once occupied this area. Those which lie within the Valparaiso moraine are principally of the irregular type of lake which occupy the irregular depressions left by glacial deposit. There are probably some kettle hole lakes which are formed by melting of buried masses of ice within the moraine. This type of lake is small, nearly circular and deep. They are usually closely associated with the irregular type and are sometimes hard to distinguish from them. The group of lakes which lie west and north of LaPorte are of the irregular type. The group of lakes of which this paper treats specifically form a crescent partially within the city limits and partially on the northwest edge of the city. The limbs of the crescent point north and beginning with the northeasternmost lake we find, Lower, Clear, Lily, Stone, South Pine and North Pine, the last forming the northwest limb. On the northeast limb to the north of Lower Lake are three other small lakes, Lower and Upper Fishtrap and Horseshoe Lakes. These three lakes, however, are detached from the other groups by considerable divides and lie at considerably different levels so are treated only incidentally in this paper.

Status of Lakes at Earliest White Settlement. The six lakes named in the first group above are remnants of two lakes which existed when white settlers first came to this region. Lower, Clear, Lily and Stone lakes were then parts of one lake the extent of which is shown in figure 2. The elevation of this lake was about thirteen feet higher than the present level of Clear Lake or about 804 feet above sea level. The two Pine lakes were united at that time and the extent of this lake is shown in figure 2. The elevation of this lake was about twenty feet higher than the present level of North Pine Lake or about 809 feet above sea level. The divide between these two lakes was a low narrow ridge through which a channel was cut to allow the passage of a small steam boat. This boat was used to convey passengers from LaPorte to the Old Baptist Assembly ground on the north end of North Pine Lake where Pine Lake Village now stands. This steamer discontinued operation about forty years ago. During these early years Clear Lake had an outlet overland through the city of LaPorte somewhat north of the business section. This outlet ceased to flow forty or fifty

[1] Monograph LIII, U. S. Geol. Surv.

years ago according to the testimony of early settlers. Thus the decline of the lakes began long ago. However, the old shore lines, with their small terraces and small wave-cut cliffs, on which stand large trees whose lake side roots are deformed by ice and wave action, remain as mute testimony to the survey of 1829 when the extent of these lakes was as shown in figure 2.

Relation of Original Lakes to Present Lakes. Since the overland channel of Clear Lake has been closed the entire drainage of these lakes has been underground. A survey of 1847 shows the area of the lakes very greatly reduced from that of 1829 and the area at present is much smaller than that of 1847. The areas of the two lakes shown by the survey of 1829 and the areas of their present remnants as determined by planimeter from figure 2 are as follows:

North Lake of 1829	1.388 sq. mi.	North Pine Lake	.167 sq. mi.
		South Pine Lake	.275 sq. mi.
		Total	.442 sq. mi.
		Per cent of former lake	31.4
South Lake of 1829	1.317 sq. mi.	Stone Lake	.196 sq. mi.
		Lily Lake	.020 sq. mi.
		Clear Lake	.135 sq. mi.
		Lower Lake	.035 sq. mi.
		Total	.386 sq. mi.
		Per cent of former lake	29.3

From this we find that the areas of the two original lakes were very near the same and that the present remnants are not far different from each other, each representing about 30 per cent of the original. The levels of the remnants are fairly uniform. It is interesting that North Pine Lake is the lowest of the group and each lake of the crescent is slightly higher until Lower Lake at the other end of the crescent which is the highest. The following figures show the elevations of the various lakes as determined by Burtis Thomas, City Engineer of LaPorte, in December, 1921, and my own check on North Pine and Clear lakes in June, 1922, during a severe drought:

Lower Lake	792.75 feet (Thomas)		
Clear Lake	791.76 feet (Thomas)	791.62 feet	(Check)
Lily Lake	791.31 feet (Thomas)		
Stone Lake	790.40 feet (Thomas)		
South Pine Lake	789.58 feet (Thomas)		
North Pine Lake	789.31 feet (Thomas)	788.59 feet	(Check)

Figure 3 shows the elevation of Lily Lake from 1898 to 1914, inclusive. The record of the lake level was kept by the city waterworks employes for each day during this period. The elevation indicated for any year on this graph was derived by averaging the level readings for the first day of each month during the year. The monthly fluctuations were slight so that this gives a comparatively accurate elevation for the year. To convert these readings to the datum of sea level add 762.32 feet. This graph shows that Lily Lake fluctuated in this period

between low level of 29.42 feet (791.74) in 1901 and high level of 33 feet (795.32) in 1909. At the beginning of the period the lake stood at 793.19 feet and at the end at 792.79 feet. The average for the whole time was 793.13 feet. These elevations compared with the elevation of 791.31 feet late in 1921 shows a decline of less than two feet since 1898. Thus the general decline in Lily Lake has been comparatively small since 1898 if the records are all correct. Records upon other lakes are not available except occasional records upon Clear Lake which have been kept by Mr. W. A. Cummings, Park Superintendent, who asserts that Clear Lake has declined five feet or more in the last eight years.

Relation of Lakes to Ground Water Table. This group of lakes has no inlets except sheet drainage of very small areas and has no outlet. Therefore the lake levels are evidently maintained by ground water.

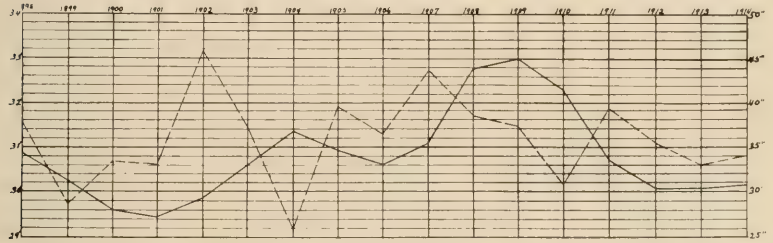

Fig. 3. Graph showing relation between the rainfall and the level of Lily Lake, Laporte, Indiana, from 1898 to 1914. Rainfall shown by broken line and referred to inches at right. Lake level shown by solid line and referred to feet at left. Datum of city bench mark.

The lake levels stand at the level of the water table. They rise and sink with the water table. So-called airholes in the ice in winter indicate that there are springs within the lakes which means that there is addition to the lakes by ground water. The mean annual rainfall at LaPorte is 36.83 inches[2], and the annual evaporation from free water surfaces is about 34 inches[3]. Thus, it is evident that these two factors almost balance each other with a small margin in favor of the increase of lake volume. Also, since there is a constant decline of lake level it is evident that there must be a loss through ground water movements.

Inasmuch as the movements of ground water are dominated by static head or steepness of slope and porosity of the material through which the movement takes place, the slopes to various possible outlets for the underground water from these lakes have been determined. These slopes are indicated in the following table.

[2] Condensed Summary of Climatological Data for 1915 by J. H. Armington, Indianapolis, Indiana, U. S. Weather Bureau.

[3] Russell: Monthly Weather Review, Dec. 1904.

TABLE 1. Elevations of low points about Clear Lake in relation to the elevation of Clear Lake, and the fall per mile.

Point	Elevation, ft.	Fall from Clear Lake, ft.	Distance, mi.	Fall per mile ft.
Clear Lake	791.62			
Outlet of main sewer	769.77	21.85	2.75	7.94
Kankakee River at mouth of Mill Creek	712.70	79.92	15.00	5.33
City wells in Little Kankakee Valley	740.00	51.62	3.87	13.34
Springs north of divide near Springville	724.00	67.62	4.00	16.90
Pine Lake	788.59			
Springs	724.00	68.59	3.00	22.86

Note: The last two show same relation between Pine Lake and Springs north of divide.

This table shows that the static head in feet per mile from Clear Lake to the springs north of the divide is slightly greater than that to the city wells which is the greatest to points south of the divide. The static head from Pine Lake to the springs is much greater than from Clear Lake. Since the material toward the north in the moraine is coarser than that at the edge of the moraine on the south, both slope and porosity indicate that the loss of water from the lakes is mainly northward. Clear Lake seems to be near the ground water divide and probably loses water in both directions.

Hypothesis of the Actual Water Loss from Lakes in Ten Years. The data concerning the actual decline in lake level for the past ten years is somewhat contradictory. Figure 3 shows Lily Lake to have been 793.19 feet elevation in 1898, and 792.79 feet in 1914 while the elevation at the end of 1921 was 791.31. These data indicate less than two feet fall since 1898. On the other hand the data collected by Mr. W. A. Cummings at intervals of a year or less for seven or eight years indicate that Clear Lake has declined five or five and a half feet in that time. The testimony of reputable citizens seems to bear out Mr. Cummings' data. These citizens point out definite points along the shores of Pine and Stone Lakes where the water stood ten years ago and these points are invariably about five feet above the present water level. It may be that the bench mark from which the data on Lily Lake was taken was not accurately located and was considered several feet lower than it actually was. This seems probable for it is not reasonable to think that Lily Lake was lower in that time than were the other lakes which would be the case if we recognize Mr. Cummings' data and the

testimony of citizens as authentic. However, the data on Lily Lake can be considered authentic so far as fluctuation is concerned.

The decline of five feet in the level of this group of lakes has greatly reduced its area. By estimate the present area is slightly more than half the area when the lakes stood five feet higher. If we consider that area to have been twice the present area it gives us a working basis to determine the actual loss of water in the ten years. The area of the present lake surface is .828 square mile. The former area if twice as large was 1.656 square miles. The average area for the ten years has been 1.242 square miles, which is 34,624,972.8 square feet. The volume on this average area to five feet deep is 173,124,846 cubic feet, the water loss in ten years. Thus, the loss per year has been on the average 17,312,485 cubic feet. This loss has been much more rapid than in the preceding years according to the testimony of citizens and according to the record kept at Lily Lake. While the consistent loss since white settlement of this region can be explained by deforestation and systematic drainage of the land, the increased decline within the last ten years is no doubt due to the installation of the sewage disposal system in the city of Laporte.

Apparent Relation of Lake Level to Ground Water Level Prior to Installation of Sewage System. When white settlers came to this region and for a long time thereafter Clear Lake drained eastward through the present city of LaPorte. During that time Clear Lake stood at a lower level than Pine Lake. This is shown by the levels of the old shore lines. Even at that time, however, there was underground drainage from Pine Lake through the Valparaiso moraine to the springs whose location is shown in figure 1. There is every indication that this drainage existed because of the steep gradient shown in table 1. Some idea of the drainage of the region north of these lakes and no doubt of the lakes themselves may be gained from observations at Harding Pond, Section 22. Considerable areas north of this pond are drained into it by tile drainage, one an eighteen-inch tile. During heavy rains this tile and others flow full into the pond and fill it up to a certain level above which the lake does not rise. Neither is there indication of water entering Pine Lake from this pond. The two are separated by a divide over fifty feet above Pine Lake. The distance from the pond to Pine Lake is about one-half mile and the difference in elevation 10 feet. Thus the gradient from Harding Pond to Pine Lake is 20 feet per mile but the springs north of the moraine are 75 feet lower than the pond and two and one-half miles away. Thus the gradient to the springs is 30 feet per mile.

The peculiar topography of this moraine with its abrupt northern slope leaves the whole southern slope perched so high above it that the tendency of the ground water below lake level is to pass beneath the moraine and appear at the springs. There are no large springs on the south side of the moraine. The material of the moraine is principally gravel and sand while that of the Kankakee lowland is fine sand and clay. There is every evidence that there is a deep seated underground drainage even from the Kankakee valley itself toward Lake Michigan.

Figure 4 illustrates the general idea. In order to prove this point a well test was made to determine the direction of ground water flow on the north shore of North Pine Lake at the point indicated by the letter W in figure 2. The point selected for the test was located fifty feet from the present lake shore, about five feet above present lake level on the old lake bed. A three-inch well was sunk to a depth of twenty-nine feet, which brought it to the level of the deepest point in Pine Lake. The deepest point in Pine Lake was 24 feet, located three hundred feet directly out from where the well test was made. Using the three-inch well as a center and a radius of six feet, a circle was described. On this circle at the cardinal and intercardinal points two-inch wells were sunk to the same depth as the three-inch well. The water rose in these wells to various heights from 2.73 to 3.08 feet below lake level. This circumstance proved that the ground water was not moving toward the lake at the surface of the lake. Some of the wells

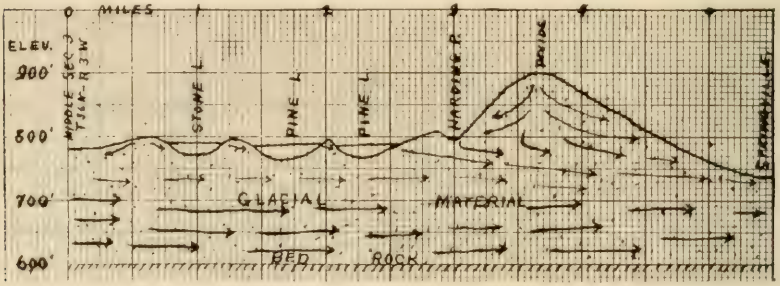

Fig. 4. Cross-section from middle of section 3, T. 36 N., R. 3 W. northward through Stone and Pine Lakes and Harding Pond, to Springville, showing probable ground water movements.

had clay pockets in the drilling and these wells stood at the highest level. All the wells were in gravel at the bottom.

At six a. m., July 4, 1922, the center well was charged with fluorescein, which colors the water a vivid green. Samples were taken from the outer wells each hour during the afternoon. At 7:00 p. m. a faint color was detected in the northwest well which became distinct at 7:15. Thus the ground water at that point was moving northwestward at the rate of six feet in thirteen hours, 11 1/13 feet per day. If this rate is uniform the time necessary for it to travel to the springs north of the divide is almost four years. This is rather rapid for ground water flow but the rapidity is due to the gradient of twenty-two feet per mile and the coarse sand and gravel through which the flow occurs.

The result of this test when associated with the fact that the lake levels are successively lower from Lower to North Pine and that there are overland channels which flow from Lily to Stone and from Stone to South Pine part of the year leaves no room to doubt that the principal ground water drainage from the lakes is from North Pine northward.

Springs Between Springville and Bakerspoint. A careful examination of the springs north of the moraine was made. The springs issue from the hill slope in bogs which sometimes cover several acres. Within these bogs the whole surface is filled with water and trembles as one steps upon it. In wet weather it is impossible to walk across them. The highest of these bogs was at an elevation of about 724 feet. From the bogs the water immediately forms a definite stream which flows down a steep slope until it joins Trail Creek. The seven springs shown as tributary to the east fork of Trail Creek (figure 1) discharged on June 22, 1922, 2.8628 cubic feet per second. This measurement was carefully made by weir and calculated by Francis' formula. The western one of these springs was by far the largest and discharged 1.75 cubic feet. No measurements were made on the springs tributary to the west fork of Trail Creek but the two forks are not far from the same size. The measured discharge amounts to 90,181,260 cubic feet per year. From the topography of the region it appears that about twelve square miles drain through the moraine in the vicinity of LaPorte. The discharge of the springs would account for about three and one-half inches of rainfall over this area. Since no measurements were made on the springs on the west fork of Trail Creek that discharge would account for considerable more. Since the rainfall is about thirty-six inches and the run-off usually about 25 per cent to 35 per cent, the amount to be accounted for would be about 9 to 12 inches. Therefore it is evident that these springs account for a considerable percentage of the drainage of this region.

Figure 8 has already been discussed to some extent on page 86 of this paper. The rainfall data shown in this graph was taken from reports of the United States Weather Bureau for LaPorte and are referred to inches on the right of the graph. It will be noticed that the lake response to heavy or light rainfall occurs two years later. An analysis of the graph shows an interesting relation. Low rainfall occurs in 1899 and low lake level two years later; high rainfall in 1902 and high lake level two years later; low rainfall in 1904 and low lake level two years later; high rainfall in 1907 and high lake level two years later; low rainfall in 1910 and low lake level two years later. Two slight contradictions to this response occur. A slightly diminished rainfall in 1906 has no corresponding depression of lake level in 1908 and relatively high rainfall in 1911 is not succeeded by high lake level in 1913. The latter case can be explained by the fact that the city water was drawn from the lake from July, 1908, to November, 1912. This fact may also account for the rapid decline of the lake from 1909 to 1912. The responses are too regular to be accidental and there must be some cause for it.

Hypothesis to Explain Responses of Lily Lake Level to Rainfall. The response of Lily Lake and probably of the whole system to the rainfall cannot be explained by the influence of any condition near at hand. While the actual movement of ground water from the crest of the moraine north of the lakes to them, if such movement takes place, would probably require two years, yet the rise of the water table at that point would show its influence much sooner. It is my opinion that

this response comes from a stimulus in the great morainic area of Steuben County and vicinity. Figure 5 shows the general idea. It is an interesting thing that artesian wells occur at many points between Steuben and LaPorte Counties. At South Bend there is a lens of impervious clay as shown in figure 5. A well drilled into the gravel beneath this clay will overflow in the lowlands along the St. Joseph River while a well sunk into the gravel above the clay will not overflow. In other places in this vicinity the same condition exists. The same influence communicated to the bottom of the lake system at La Porte would influence its level. The position of these lakes at the edge of the great clay deposits of the Kankakee lowland would account for the hydrostatic head by which the lake level is sustained slightly above this lowland. The response to the static influence from this great distance would lag far behind the stimulus. I know of no experiment or investigation which has ever been made to determine the rate of response of stimulus from hydrostatic head through rock. No conclusive

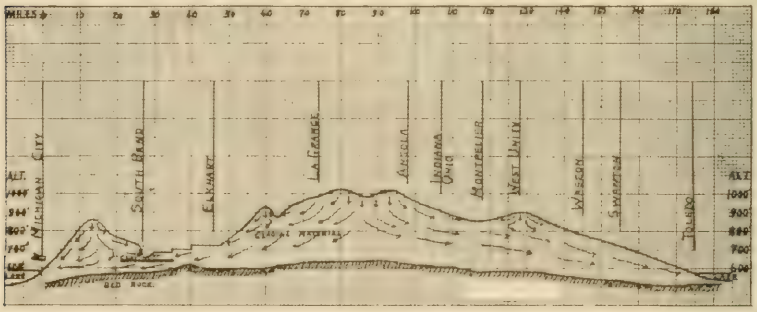

Fig. 5. Cross-section profile from Lake Michigan to Lake Erie showing major ground movements as dominated by major relief features.

statement as to the cause of the response shown in figure 3 can be made, but as before stated the responses are too definite and persistent to be ignored.

Apparent Effect of Installation of Storm Sewage System in La-Porte upon the Lakes, with Explanation. The storm sewage disposal system of LaPorte was constructed in 1912-13. The extent of the main lines of this system is shown in figure 2. Laterals extend to all parts of the city along these mains. All that part of the system north of the junction of the Fifth Street main with the main sewer line is above the level of Clear Lake. Following the installation of this system there has been a rapid decline in the level of the lake system. As previously stated, Mr. W. A. Cummings, Park Superintendent, has determined this decline to have been about five and one-half feet in eight years. Because of the coincidence of the beginning of the rapid decline of the lake level with the installation of the sewage system it is apparent that they are related.

The soil underlying the city of LaPorte is principally sand and gravel with small amounts of clay. Formerly much of the water which

fell in the city as rain entered the soil and became ground water. Thus, the water table was held up. After the installation of the sewage system the storm water was drained directly from the streets into the sewers. As a result there was a loss of water to the water table and it declined. Mr. J. W. Good, well driller of LaPorte, stated that he finds the water table about seven feet lower now than at the time of the installation of the sewer system. He states that the water table is now from twenty-eight to thirty feet beneath the surface of the city. The city bench mark on the court house lawn is at 812.32 feet elevation. Therefore the water table, according to Mr. Good, is at 782.32 to 784.32 feet elevation. If we consider the present water table as being at 783.32 feet elevation in the business section of LaPorte, seven feet lower than in 1913, and Clear Lake at 791.76 feet elevation or five and one-half feet lower than in 1913, we have the following comparison of levels:

	Clear Lake Level	Water Table Level	Difference
1913.....	797.26 feet	790.32 feet	6.94 feet
1922.....	791.76 feet	783.32 feet	8.44 feet

If we now consider the business section of LaPorte as one-half mile from Clear Lake, we find that the fall of 6.94 feet in the half mile is practically the same as the fall of 13.3 feet per mile toward the city wells (see page 88). By the installation of the sewage system the water table was lowered about Clear Lake, thus steepening the water table slope. This slope is still steeper than it was before the installation of the sewage system, so it may be that Clear Lake will decline further. Since the supply of water to the lakes was not increased when the sewage system was installed and the water table lowered on this side of the lake it serves the same purpose as removing a retaining wall from the side of a pond except that the response is slower due to the very slow movement of the ground water.

Proposed Plans for Restoring Lake Levels. On page 89 the average loss of water per year from the lake system for the last ten years is given as 17,312,485 cubic feet. Any means of restoring the lakes to their former level must therefore furnish at least this much water. Two plans are suggested. The first is to reverse the storm sewage of the city into Clear Lake. All of the system north of and including the Fifth Street sewer could be reversed. The area drained by this part of the system is about two square miles and the annual rainfall on this area slightly more than thirty-six inches. If we consider that the sewers carry away one-tenth of the water which falls within the area drained by them the amount disposed of during the year would be 16,727,040 cubic feet or almost enough to supply the deficiency. Since it is highly probable that much more than one-tenth of the rainfall is disposed of by the sewers and since the average loss per year to the lakes is probably considerably over-estimated, this reversal of drainage would probably be sufficient to prevent a further decline of lake level and also tend to raise the level.

A second plan is to drain areas of the morainic area north of the lakes into them. As previously pointed out, there is now little of this area draining into the lakes. However, between the lakes and the crest

of the moraine there are about 3,500 acres which could be drained into the lakes. Three lines of drainage are suggested and shown in figure 2. The eastern line of drainage beginning in section 14 would drain an area of about 1,000 acres without laterals and possibly half that much more by lateral connections. This drainage introduced into Lower Lake would silt it up and gradually reduce this lake to solid ground, which would be highly desirable, since Lower Lake is now virtually a swamp and nobody is interested in restoring it. This would admit the drainage into Clear Lake virtually free from sediment. The second line of drainage in sections 21 and 22 has already been surveyed by Mr. Thomas, City Engineer of LaPorte. It is proposed by Mr. Thomas to tunnel about 1,600 feet from Harding Pond to Pine Lake. This line of drainage would drain about the same amount of land as the former line. The third line of drainage in sections 20, 29 and 33 would drain a smaller area. The total area drained would be not less than 2,000 acres and if fully developed about 3,500 acres. The slopes along the drainage lines would vary from 30 to 50 feet per mile. The discharge delivered by these drainage lines if properly installed would vary from 25 to 40 per cent of the rainfall. This would be from 9 to 15 inches per year from the area. If the higher estimate of 15 inches from 3,500 acres is considered the discharge would be 190,575,000 cubic feet per year. If the lower estimate of 9 inches from 2,000 acres be considered the discharge per year would be 65,340,000 cubic feet. Even the lower estimate is 3.7 times the yearly loss of water from the lakes and the result of this drainage would be the immediate restoration of the lakes to higher levels.

The result of restoration of the lakes to higher levels would be to increase the ground water slopes from the lakes. In order to determine the amount of this increase we will consider a seven-foot rise in lake level. This would increase the slope from Pine Lake to the springs from 68.59 feet to 75.59 feet, an increase of 10.2 per cent. The increase from Clear Lake east to the city wells would be from 51.62 feet to 58.62 feet, an increase of 13.5 per cent. Since the movement of ground water depends upon slope and the porosity of the rock, and since the porosity would be unchanged, the increase in ground water loss would be from 10.2 to 13.5 per cent. If we consider this to be 12.5 per cent the estimated loss of 17,563,392 cubic feet per year would be increased to 19,758,816 cubic feet. This would still make the estimated discharge to the lakes over three times the estimated loss from them. I am sure the loss in this case is over-estimated and the gain under-estimated so that these figures are very conservative.

Some minor advantages would be derived by carrying out the proposed plans. Considerable areas of fertile land would be drained and made suitable for agricultural purposes along each of the three proposed drainage lines. The water table would be restored under the city of LaPorte which would restore wells to their former levels and also be of great value to the vegetation of the city. Clear Lake, which is now in the last stages of lake existence and rapidly becoming an unsightly swamp, would be made a fine open lake which would add greatly to the health and beauty of the city.

ABANDONED CHANNELS IN RANDOLPH AND DELAWARE COUNTIES, INDIANA.

FREDERICK J. BREEZE, Indiana State Normal, Eastern Division.

Extending across the massive moraine which trends east and west through southern Randolph and Delaware counties and northern Wayne and Henry counties are four broad valleys which were lines of discharge from the melting ice of the Wisconsin glacier. This moraine, which belongs to the Bloomington morainic system, needs a local name, and in this paper it is called the Mt. Summit Moraine, after the village in Henry County which stands on its crest near the place where it bends to the southwest. The northern section of each of these abandoned channels holds a small stream which flows northward. The southern portion holds a stream which flows to the south. The divide in each valley is a broad, muck swamp. (Fig. 1.)

Starting from the east, the first channel is that occupied by the headwaters of Greenville Creek and Nolands Fork. The swampy divide lies just east of Crete, a small village on the Peoria Division of the Big Four Railroad. It can be well seen from the highway that runs through Arba, Crete, and Spartanburg. The second channel lies east of Modoc another village on this railroad. The east-west highway passing through Modoc and Lynn crosses this channel near the southern edge of the broad, swampy divide. South from this swamp flows a small stream called West River, a tributary of West White River. The third channel lies east of Losantville. A small tributary of West Whitewater occupies the southern part of this valley, while the northern part is occupied by Little White River. The fourth, and largest of these glacial channels extends from the vicinity of Muncie to Newcastle. In the northern part of this valley now flows Buck Creek, a tributary of West White River. The Southern part is traversed by one of the headwaters of Blue River (East White River). A tributary glacial channel coming in from the southeastern corner of Delaware County joins the main glacial channel (Buck Creek-Blue River Valley) at a point about two miles south of the Delaware-Henry County line. Prairie Creek occupies most of the length of this old channel.

A probable line of discharge of glacial waters lies about three miles west of the eastern-most channel. The northern part is occupied by the headwaters of West White River and the southern part by Greens Fork, a tributary of West Whitewater. The divide, however, is not in a well-defined channel and therefore it has been thought best not to consider it with the other four lines of glacial outflow which are so well defined.

A. J. Phinney, M.D., in his geological reports recognized these valleys as lines of discharge of glacial waters. Writing of these valleys in his *Geology of Randolph County*[1], he says:

"The streams which occupy these broad valleys could never have excavated them; in fact, until ditches were cut, they had not even made a channel for themselves. They evidently mark the course of

[1] Phinney, 12th Ann. Rept., Ind. Dept. Geology and Natural Hist. p. 180.

"Proc. 38th Meeting, 1922 (1923)."

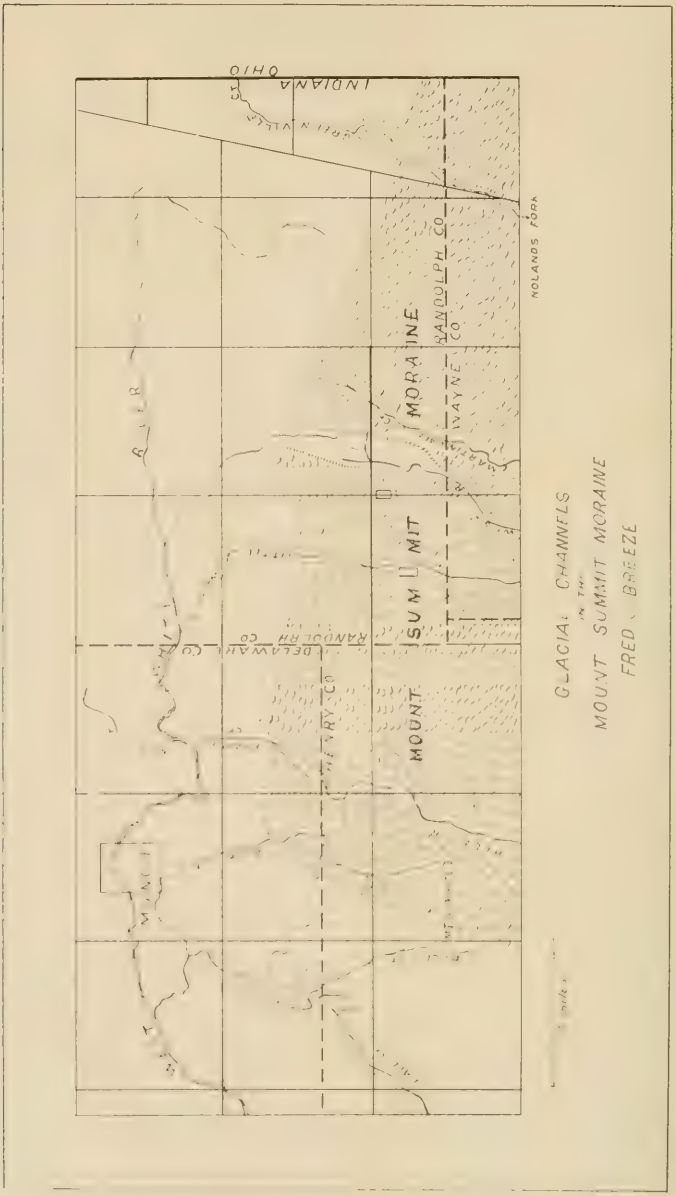

Fig. 1. Glacial Channels in the Mount Summit Moraine.

glacial rivers flowing from the northeast to the valley of the Ohio or the ocean."

Phinney[2] in describing the upper part of the glacial valley, which extends from near Selma, Delaware County, to the main glacial valley in which Buck Creek and Blue River now flow, says:

"Just west of Selma where crossed by the Bee Line Railroad it was deep enough and treacherous enough to swallow up their embankment when first built. This channel extends southwestward across the valley of White River and to the east of New Burlington into Henry County. Near the county line the channel, now called prairie, is filled up sufficiently to cause the water of Prairie Creek to flow northward to White River."

Arthur E. Taylor in *A Soil Survey of Randolph, Wayne, Henry, Rush, Fayette, Union and Franklin Counties*[3] in describing the Buck Creek-Blue River Valley, says:

"A very interesting problem in stream piracy was noted by the writer in the northern part of Prairie Township (Henry County), but time did not permit him to work it out in detail. * * * Blue River once entered Henry County two and a half miles east of Luray and drained a considerable area in southern Delaware County. Subsequently Buck Creek, with a lower channel, kept working its head back towards Blue River, and finally, at a point one mile south of the Delaware line, captured it, conveying the water in a northwesterly direction to the White River. Blue River was left as a small creek which was entirely too small to keep the old river channel open. * * * A marshy condition began to develop, and a large amount of vegetation accumulated in the presence of water, which is seen today in the muck beds and the dark Wabash silt loam and Wabash loam soils that cover the surface."

The continuity of the Buck Creek-Blue River Valley is not due to stream piracy. The whole valley gives evidence of having been excavated by a large stream flowing southward. The only piracy is that of the channel.

In many moraines are shallow gaps which served as spillways for the water from the melting ice, but the floors of these gaps are far above the level of the bordering plains on the outer and inner sides of the morainic ridges. These four abandoned channels are unusual in that their floors have been excavated down to the level of the bordering plains. It seems that they served as glacial channels for a considerable time after the ice had retreated from the inner slope of the Mt. Summit Moraine.

The large terraces along East White River in Henry and lower counties and along the streams of the Whitewater system, as well as the extensive gravel plains in Wayne County are a measure of the enormous volumes of glacial floods that poured through these channels.

[2] Phinney, Henry County and Portions of Randolph, Wayne, and Delaware: 15th Ann. Rept., Ind. Dept. Geology and Natural Hist.

[3] Taylor, A. E., 34th Ann. Rept., Ind. Dept. of Geology and Natural Resources, pp. 74, 75.

The land north of the Mt. Summit Moraine slopes to the west and the present drainage is in that direction. After the ice retreated north from this moraine in Randolph and Delaware counties, a dam, presumably a part of the ice sheet, still lay to the west and southwest. When this dam of ice melted away a lower outlet was opened up and these four valleys leading southward ceased to carry water from the melting ice.

After these valleys were abandoned by glacial waters, they received only the run off from short, transverse tributaries flowing from adjacent areas of the moraine. The small volume of water spreading out over the broad valley floors was unable to keep the channels open; and alluvial fans spreading out across the valleys soon converted the valley floors into a series of shallow basins in which thick beds of peat and muck accumulated. In time the postglacial streams to the south of the moraine worked back by headward erosion into these swampy areas, while tributaries of West White River, cutting back southward, came into them from the north.

Natural drainage was so poorly developed that it was necessary to dig large ditches to convert these swampy tracts into productive lands. Today these areas of rich black soil yield heavy crops of corn.

A striking feature of the broad belt of muck land which has been reclaimed by the dredging of Buck Creek and Blue River is the large amount of buried wood in it. In places farmers have dug up cords of wood closely resembling red cedar and used it for fuel. Large pieces may still be found just beneath the plow soil. Samples of this wood collected by State Forester Deam and the writer are in the State Museum at Indianapolis.

Southwest of Muncie is a valley which seems to have been excavated by a single stream, although at present two streams occupy it. In the northern part is Bell Creek which flows north into Buck Creek. In the southern part is Fall Creek. Between the two there is a portion of the old valley which is not cut by a stream channel. It is a broad swampy divide. The tributaries of these two streams (not well shown on the map), when studied in reference to the old valley, present some striking features. Since this old valley lies wholly on the northwest, or inner, side of the moraine it is merely mentioned here. It will be described in a future paper.

SOME CONTRASTS BETWEEN GEOGRAPHIC REGIONS IN INDIANA.

STEPHEN S. VISHER, Indiana University.

Indiana is strikingly uniform in many ways. There is comparatively little regional difference in rainfall, in temperature, or in altitude. Nevertheless, minor contrasts occur in Indiana in respect to many geographic conditions and have several significant effects.

Some of the contrasts which may be mentioned are those of climate, of types of soils, of altitude, of relief, of drainage conditions, of relations to waterways and railways, differences in farming practices, in chief crops grown, and in the conveniences and equipment in and about the farm home.

Temperature Contrasts. There is an average difference of about 5° F. between the southwestern corner of the state and the northern part, a difference of nearly 6° in summer and 8° in the maximum temperatures. The northeastern corner never has had an official temperature above 103° while the southern part has had a temperature of 111°. The sectional differences between the lowest temperatures ever recorded is somewhat less. The lowest is 33° below zero at Lafayette, while a temperature of 28° below has been officially recorded from Paoli and Jeffersonville. These differences in temperature are due chiefly to the differences in latitude, but are partly due to differences in altitude, the southwest corner of the state being within 350 feet of the sea level, while the northeast corner is above 1,000 feet.

The growing season, or the period without killing frost, in the southwest third of the state usually is nearly a month longer than in the northeastern corner. However, the frost-free season near Lake Michigan is, on the average, a week longer than somewhat farther south. The lake is comparatively warm in the autumn. Spring frosts occur near the lake as late as they do farther away but they do less damage to fruit trees because the cold winds from the lake and the cloudiness prevent early growth.

Contrasts in Rainfall. There are two chief types of sectional contrast in rainfall. The southern part of the state receives several inches more per year, but a larger fraction falls in the cooler six months than is the case in the northern part of the state. In the southern half of the state the average rainfall is 40 to 45 inches, while in the extreme northwestern corner of the state only 33 inches are received. In general, each month of the year receives about three inches of rain, but in the northern half of the state, about 55 per cent of the year's total falls during the warmer six months, while in the southern part of the state 50 per cent is received in that season. In the extreme northwest, 60 per cent of the precipitation comes in the warmer season, when it is most needed. The decrease in rainfall northward is related to the increased distance from the Gulf of Mexico, the one great source of rainfall for Indiana. The larger percentage in summer to the north is related to the fact that in winter, moisture carried northward by

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winds from the Gulf is dropped sooner than in summer because the continent is cold in winter compared to the ocean while it is comparatively warm in summer.

Snowfall. The part of the state near Lake Michigan receives three times as much snowfall as does the extreme southern part. (30 inches versus 10 inches.) Furthermore, it does not melt nearly so soon in the northern area, in fact it often remains on the ground for weeks, although it seldom lasts more than a few days in the extreme south end of the state.

Soil Contrasts. The soil shows many local differences, but the U.S. Bureau of Soils recognizes only five main soil regions in Indiana. The

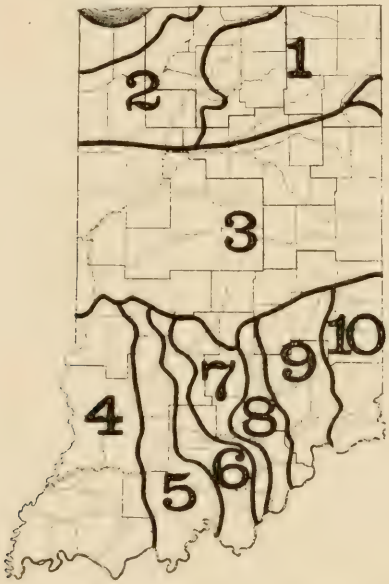

Fig. 1. Physiographic Regions of Indiana. 1=Morainal, 2=Kankakee, 3=North Central or Tipton Till Plain, 4=Wabash Lowland, 5=Crawford Upland, 6=Mitchell Plain, 7=Norman Upland, 8=Scottsburg Lowland, 9=Muscatatuck Slope, 10=Dearborn Upland. (After C. A. Malott).

great central section and much of the northern fourth are covered with a glacial clay loam. Considerable areas in the northwestern quarter are very sandy, while others have the famous brown soils of the northeastern Illinois corn-growing region. In southern Indiana, old glacial soils are found on the east and on the west, while soils derived from sandstones and those derived from limestones cover most of the middle portion of the southern third of the state.

Topographic Contrasts. In respect to relief or ruggedness, four main types may be recognized: (1) Prevailingly smooth to gently undulating, which is the characteristic condition in many counties in central Indiana. (2) Prevailingly gently rolling to rolling, which is true of

much of the southeastern quarter of the state, of a wide belt along the western side of southern Indiana, and also in many areas in central Indiana and northern Indiana. (3) Prevailingly rolling to hilly. This type is found in the lake region of the northeastern quarter, and is represented along the valleys of many streams, notably the Wabash northeast of Vigo County, and along the Whitewater. (4) the roughest part of the state is found along the Ohio River and in the unglaciated middle portion of southern Indiana.

The three-fold division of Indiana, which has often been made, that is Southern, Central and Northern, is largely based on characteristic differences in relief, but partly on differences in soil. Northern Indiana is the portion north of Benton County and the Wabash River. It contains many moderately rough areas, and considerable sandy soil, as well as muck land. Most of it, however, possesses a good glacial clay loam soil. Central, or north central Indiana is prevailingly level to gently rolling and possesses an excellent soil. Southern Indiana is the southern third of the state. These three great physiographic regions are shown in the accompanying map. (Fig. 1.)

Contrasts in Respect to Drainage. With respect to drainage conditions, most of southern Indiana was originally fairly well drained; most of central Indiana has been artificially drained, while large areas in northern Indiana are still undrained. The lakes and marshes of the state are nearly all in this northern section. More than half of southern Indiana was not glaciated while the remainder was glaciated much longer ago than was the case in central and northern Indiana.

Contrasts in Respect to Relation to Waterways. During the early settlement of the state, the relation to navigable streams was important. Then the southern margin, along the Ohio River, and the part along the lower Wabash were much better favored in transportation facilities than the rest of the state. The settlement of the part of the state nearest Lake Michigan was comparatively little affected by the lake because of the belt of sand dunes and marshes which separate the lake from the productive back country.

Later the canal built from Lake Erie to Evansville gave what was then considered a good means of transportation to a narrow strip. The spread of the population over the state from decade to decade reflects the importance of the waterways as highways. The population was fairly abundant along the Ohio, Wabash and Whitewater rivers when there were almost no settlers in large sections elsewhere in the state. Not until the railroad era commenced, about 1850, did the large areas of very sparse population disappear from the northern part of the state.

Regional Contrasts in Railroads. Today, in contrast, the northern two-thirds of the state is much better supplied with transportation facilities than is most of the southern third. There are two southern counties which have no railroads and several which have only a small mileage. Furthermore, a considerable share of the mileage in southern Indiana is of branch lines with inferior service. The chief reasons for this condition are, (1) the roughness of much of southern Indiana with the consequent difficulty in railroad building; (2) the lesser demand for trans-

portation in southern Indiana, which in turn is related to the greater poverty of the region and to its fewer industrial centers; (3) the fact that many more east-west trunk lines cross northern Indiana enroute to Chicago or St. Louis than cross southern Indiana.

Variations in Farms. The contrasts between different regions in the state are well illustrated by differences in the average value of the land. While according to the 1920 Census, the state average was $104 per acre, the Crawford Upland (figure 1, region 5) averaged only $26 per acre, and the Norman Upland only $31, but the wide, almost level north central region had an average of $158. The average values in the remaining regions outlined in figure 1 are as follows: 1—$102; 2—$91; 4—$71; 6—$32; 8—$74; 9—$43; 10—$51.

The variation in the per cent of land in farms is not so great, ranging from 82 per cent in the Norman Upland to 98 per cent in the Dearborn Upland. The wide central plain had 95 per cent of its land in farms. Other regions varied as follows: 1—92; 2—89; 4—88; 5—90; 6—89; 8—90; 9—93.

One might expect that the richer land of central Indiana would be divided into smaller farms than the poorer land in southern Indiana because a smaller acreage can support a family. But instead, the smallest farms, on the average, are found in the Norman Upland, of which Brown County is representative. There the average is 88 acres, in contrast with 114 acres in the north Central plain and 168 acres in the Kankakee region. The average size of farms in the remaining regions are as follows: 1—101; 4—94; 5—110; 6—101; 8—107; 9—99; 10—94.

Not only are the farms larger than the average in the smoother central part of the state, but a larger proportion of the land is in crops and a smaller proportion in pasture, wood lots and waste land. This is illustrated by the total land devoted to cereals per average square mile. The north central plain with 350 acres out of each average 640 acres has three times as large a share of the land in cereals as the Norman Upland with 117 acres. Other regions have intermediate acreages as follows: 1—259; 2—298; 4—282; 5—144; 6—164; 8—296; 9—172; 10—165.

The contrast in the total taxables per average square mile is great, and very important. The richest part of the state, the north central plain, has taxables assessed at $214,000 per square mile, on the average, whereas in the poorest region, the Crawford Upland, the valuation is $34,000, only about one seventh as much. No wonder that the schools and roads are better in the former region than in the latter! The valuation in other regions is as follows: 1—$112,000; 2—$88,000; 4—$122,000; 6—$40,000; 7—$61,000; 8—$103,000; 9—$50,000; 10—$60,000.

Accompanying these notable contrasts in the semi-permanent assets of the several regions, there is a conspicuous contrast in improvements and equipment on the farms. For example, one area, the Muscatatuck Slope, has six times as many silos in proportion to area as another area, the Norman Upland. Automobiles are least frequent, 2.3 per square mile, in the Crawford Upland, where roads are very poor

and the land is least valuable and the total taxables smallest. They are more than twice as abundant in the central plain and in the Dearborn Upland, both well developed regions. The automobiles are not only more numerous in the richer part of the state than in the poorer, but they average distinctly more costly per car. Tractors are six times as abundant in the north central plain as upon the Norman Upland. Indeed they are two or three times as abundant in the central and northern part of the state as in the southern, with its large areas of rough land. The distribution of auto trucks, however, is distinctly different from that of automobiles and tractors. Trucks are relatively most numerous in the Norman Upland, a region poorly supplied with railroads. They are least common in the Kankakee region with its many low and sandy areas and its many railroads converging towards Chicago. Milking machines are three times as numerous in the northeastern morainal section of the state as in the extreme southeastern or in the Scottsburg Lowland. Running water in barns is rarest in the regions of cheapest lands, the Norman Upland and Crawford Upland. It is commonest in the Scottsburg Lowland and in the morainal region with its extensive dairying.

Within the homes there is no less regional contrast than in the barns and in the value of the land. For example, according to figures given in the Indiana Yearbook, washing machines are six times as frequent on farms in the north central plain as in the Norman Upland and vacuum cleaners are four times as common in the plain as in the rougher sections. Furnaces are more than four times as common in the coolest northeastern section than in the poorer areas of southern Indiana. Electric devices in the farm home are 60 times as numerous in proportion to area in the Kankakee region than in the hilly and rather remote Crawford Upland. Kitchen sinks are three times as common in the north central plain and the morainal region as in the Norman and Crawford Uplands.

The reasons for the foregoing contrasts are largely due to the geographic differences mentioned in earlier pages. The effects of the differences in levelness, soil, climate and accessibility, are supplemented by differences in the education and ability of the people which are in turn related to differences in opportunities. Undoubtedly there is a tendency for many of the more alert young people to go from the less favored regions to the more favored. The discouragement afforded by the small, poorly equipped farms of the less favored areas is increased by the lower average yields per acre of important crops. For example, even along the relatively productive valley bottoms of the Norman and Crawford Uplands, the corn yield is not great enough to give those regions much more than half the average yield on the wide north central plain. Furthermore, so little land is suited to corn in the rougher parts of the state that the average farm had only about a third as many acres as the average farm in the central plain. In respect to wheat there is less contrast. According to the 1920 Census, the average yield in the Crawford Upland was 12, bushels in 1919, but 19 bushels in the Kankakee region. In the three upland regions of southern In-

diana the average farm contained less than 10 acres of wheat in contrast to about 20 acres in the Wabash and Scottsburg Lowlands.

Oats are relatively most important in the northwest part of the state (Kankakee region) where they occupy several times as large a percentage of the land as in the southern third of the state. They also yield far better in the northern than in the southern parts of the state. It may be due in part to the earlier coming of hot weather towards the south than towards the north. Oats, like wheat, stools more heavily and hence yields best where there is a considerable period of somewhat cool weather for it to grow in, before hot weather causes it to head out. Hay and forage are relatively most important in the rougher morainal section of the northeastern corner of the state and are least important in the poorest section of the state, the Crawford Upland of southern Indiana.

Contrast in the Value of Crops Grown. On the average, the poorer counties of southern Indiana each grew crops worth nearly $1,500,000 in 1919, while the better counties in the north central section grew crops worth about $8,000,000. The contrast between the poorest and the best counties in crop production thus is about as one is to eight, when comparative area is considered.

Sectional Contrasts in Manufacturing. In manufacturing there is much more contrast than in crops. Warren County, the county which does the least in manufacturing according to the last Census, produced only one eight-thousandth as much wealth by manufacturing as did Marion County, and only one eleven-thousandth as much as did Lake County. The value added by manufacturing in Warren County was only $16,000 in 1919 while that in Marion County was $136,000,000 and that of Lake County, $180,000,000. Four other counties did less than $100,000 worth of manufacturing in 1919. Strange to say, four of these five counties are in the northwestern part of the state near counties which do much manufacturing. Three of them do less manufacturing than Brown County which is the least active of the southern counties. However, when all of the southern counties are compared with the central and northern counties it is seen that southern Indiana is as backward in respect to manufacturing, on the average, as it is in so many other respects.

Fuller data concerning many of the foregoing points may be found in the author's Geography of Indiana, which is Part I of the Handbook of Indiana Geology, recently published by the State Department of Conservation, Indianapolis. The tables upon which these contrasts in agriculture and farm equipment are based are given in the Economic Geography of Indiana, soon to be published by D. Appleton & Company, where many other points mentioned above are presented more fully.

THE PALEOLITHIC STONE AGE IN INDIANA.

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When we say "Paleolithic" in Archeology the mind is almost sure to revert to the dim and mysterious past,—perhaps as far back as the so-called pale of human existence, and we would expect that any material facts connected with it would naturally be buried in an environment so indefinite and remote that one could scarcely grasp their meaning. Such instances have been found under conditions pointing back to very early times, even to the seemingly mythical Tertiary period, but in

Fig. 1. Tertiary Sea of North America.

most cases the statistics pertaining to them have been so indefinite that they have been questioned.

"Races of Man," a very thorough and unprejudiced study of the human race, states that finders of artificially chipped flints, said to have become buried in the later Tertiary stratas, have few supporters at the present day. This can be more fully realized when we consider that the close of the Tertiary period saw the passing of the monster animals of the previous age and the coming of others more suited to a comparatively temperate climate. Large portions of the earth's crust became submerged and the ocean extended up the Mississippi Valley to the Ohio River section. California and Alaska were under water; the great Tertiary Sea spread over the western plains and up to the Arctic Ocean (fig. 1); and the coral builders were yet at work upon Florida.

"Proc. 38th Meeting, 1922 (1923)."

Agassiz says: "The earth had already its seasons, its spring and summer, its autumn and winter, its seed-time and harvest, though neither sower nor reaper was there; the forests then, as now, dropped their thick carpet of leaves upon the ground in the autumn, and in many localities they remain where they originally fell, with a layer of soil between the successive layers of leaves—a leafy chronology, as it were, by which we read the passage of the years which divided these deposits from each other. Where the leaves have fallen singly on a clayey soil favorable for receiving such impressions, they have daguerreotyped themselves with the most wonderful accuracy; and the trees of the Tertiaries are as well known to us as are those of our own time."

Following this, from causes still imperfectly known, an accumulation of ice formed in the northern latitudes and glaciers extended into former tropical sections, and one glacier period succeeded another resulting in successive deposits also containing relics of former life and growths, and in this the Quaternary period, acknowledged evidence of the existence of man appears. "Races of Man," already quoted, states that: "In the quaternary beds the presence of human bones has beyond question been ascertained. The men of that period have handed down to us implements of a very rude type: fragments of flint of pointed form,—some were found along with the bones of animals which are now extinct; and objects of bone, horn, stag's horn and shell bear witness that Paleolithic man used tools or weapons made of other material than flint. A slow sinking of the land, which submerged beneath the ocean all the countries to the north and northeast of Europe, marks the end of the quaternary period; or from the archeological point of view, the 'earlier stone age' of the Paleolithic period. Of interglacial man, maker of those first flint implements exhumed from the lowest beds of the oldest quaternary alluvia, we have at the most, for the whole of Europe, but a dozen fragmentary skulls and a score of other bones genuinely quaternary. Of these the Neanderthal skull is typical of the early Paleolithic period, having an exceedingly low and retreating forehead, prominent brow ridges and probably a low stature." The same authority also states that: "The use of the bow was only known at a later period as arrow-heads of flint or bone have not been found in the early or Paleolithic period." And, further, that: "There is no people on earth which eats its food quite raw, without having subjected it to previous preparation, and no tribe exists, even at the bottom of the scale of civilization, which is not today acquainted with the use of fire, and as far back as we can go into prehistoric times we find material traces of the employment of fire, but real cooking, even of the simplest sort, is only possible with the existence of pottery, the manufacture of which must follow closely on the discovery of a method of obtaining fire, for no example is known of unbaked pottery."

To quote still further from the same source: "The Paleolithic period was succeeded by the present era in the geological sense of the word, which is characterized, from the archeological point of view, by another stage of civilization: that of the 'later stone age' or Neolithic period. In this latter period instead of the rude flint implements of the Paleolithic period, a variety of implements made their appearance."

Just how to differentiate between the Paleolithic and Neolithic cultures is a difficult problem. In the Paleolithic period man lived as an animal, procuring food from nature's supply which in certain climates is never exhausted, until his brain development suggested the first rude weapon and the first crude cooking utensil. A recent English publication,—"Man and His Past,"—gives a method quite unique in its way. The author, Mr. Crawford, says: "Man was the first animal to grow a limb outside of himself by making tools out of wood and stone. This was a great achievement, for with man the desire outstrips the performance. There is thus added a third factor, intermediate between man and his environment; so that the different kinds of interaction between the two are multiplied enormously. Man started his career in a comparatively defenseless state, with no limb or part of his body specialized as a weapon of defense or offence. That, perhaps, is why he alone picked up and used the flint around him. Moderate in all things, he lived a life of meditative aloofness in the forest, waiting for something to turn up. His patience was rewarded, for what turned up was not any kind of external goods but the key to all such—an intelligent mind.

"Now we are in a position to understand why it was that man, and man alone, has invented tools. The close connection between tools and brain becomes clear when we realize that primitive tools were the highest existing functions of brain made manifest. The power of intelligence grows with use, for it is quick to take a hint from its teacher, the tool. The tool is improved, fresh demands are made upon intelligence to use the new tool aright, and so the process is continued, each in turn helping the other. These tools may be regarded as art-products of a primitive kind, capable, therefore, of throwing light upon the nature of the men who made them, and so form the basis of all archeological work.

"The archeologist deals with the works of man in the past; it is through them that he is able to reconstruct a picture of the condition which obtained at any given period, and trace the evolution of culture."

The author, in connection with the above, teaches an object lesson by putting the matter in shape of a formula as follows:

(Animal) ——————————————> (Object)
(Man) ——————> (Tool) ——————> (Object)

Applying the above to the principal matter in hand,—that of drawing a line between Paleolithic and Neolithic stages of aboriginal life, we can take the first portion of Crawford's formula, where there is a direct contact of animals with their environment, as representing in a general way the Neolithic age of man up to and including the use of the elementary tools. And the second portion of the formula would represent the progression in the new sphere of life as found in the various stages of advancement in the semi-civilized, aboriginal culture, known as Neolithic.

In an article entitled "Lonely Australia: The Unique Continent," H. E. Gregory says that Paleolithic man, whose primitive tools are eagerly sought in caves and gravels of Europe, was alive in Tasmania within the memory of people now living, and Neolithic man is roaming

the deserts of Australia by hundreds, some armed with a stone hatchet, a club, a short spear with hardwood point, or a long spear with stone point. What such a life would be like at the close of the Paleolithic period can be inferred by an experience of Miller and Furness among the "Village Veddahs" of Ceylon, as reported by a University of Pennsylvania bulletin a few years ago. They say: "We followed the jungle path along the eastern shore of the reservoir, dammed for the purpose of irrigating the Singhalese rice fields; this path led close to the big pads of yellow lotus, and through thick undergrowths, until we came to a cleared space where there was the merest excuse for a hut, and beside it a man and woman squatted side by side and were cooking something in a blackened earthen pot. They had between them scarcely a yard of coarse cloth for clothing. Although they had never before seen white people, nevertheless neither of them showed the slightest astonishment or interest in our appearance; both glanced up for a second, and then continued silently shelling the seeds out of the lotus pods beside them, and stirring the simmering pot over the fire. The most impressive thing about them was their inhuman apathy and lack of interest, a peculiarity of the lowest type of man. The iris of the eye seems to merge indistinctly into the white, and the Singhalese say that the Veddahs have eyes like monkeys, because they are red, and they always look down or stare straight before them; this seems to be true as at such times their faces are utterly expressionless. Near them were five other shelters or huts, about eight feet square, with scant walls and dirt floors. The women and children were occupied in shelling the seeds out of the lotus pods and the chief when asked by our guide if there were special times during the day when they ate replied: They crack one nut and eat it, then crack another and eat it, until their supply is gone, and they sleep wherever they happen to be. Although they live near the lakes, abounding in fish, they are not fishermen, as far as we could learn."

This, then, is the childlike stage in man's development, and the question comes,—Was there such a period in the existence of man in America? If primitive man here was autochthonous then as a matter of course there was such a beginning. Agassiz and Dana have stated again and again that North America was the original home of man and the oldest area known. Prominent authorities have even suggested that the tide of emigration may have set the other way—from America to Asia.

Belief in the emigration plan of peopling the so-called new-world from a "dispersal center" in Asia still obtains. The Smithsonian Institution in their Handbook of American Indians says: "The fact that the American Indians have acquired such marked physical characteristics as to be regarded as a separate race of very considerable homogenity, from Alaska to Patagonia, is regarded as indicating a long and complete separation from their parental peoples." And it is further stated: "The term Paleolithic is applied to implements, usually of stone, belonging to the Paleolithic age as first defined in Europe and afterward identified in other countries. In America the Paleolithic, as chronologically distinct from the Neolithic age, is not established, and the more

primitive forms of implements, corresponding in general to the Paleolithic implements of Europe, can be properly referred to only as of Paleolithic type."

The latest from the Smithsonian Institution on this subject is by Holmes in "Aboriginal American Antiquities," as follows: "Old world cultures have come to be known as the Early Stone, the Late Stone and the Bronze ages. In America, classification of artifacts on the basis of culture steps is not attempted. Our aboriginal history as a whole lies entirely within the so-called age of stone. A discussion of the Stone Age is a comprehensive study of the whole subject matter of the aboriginal peoples and their culture." He says further: "The purpose of the archeologist is not merely to classify and describe antiquities but to make available an intimate knowledge of all the phenomena of aboriginal culture and apply it to the elucidation of the American race and to the history of the human race as a whole." But, in order perhaps to en-

Fig. 2. Clay figures taken from below an old lava flow near the Mexican volcano Xitli. Estimated age, 7,000 years.

courage classification of artifacts on a cultural basis, he also states: "It is the privilege of the archeologist to adopt such classification and take such points of view as he believes will best serve his particular purpose, the broader purpose being to place the whole body of the subject matter on record in the manner best suited to the needs of the anthropologist-historian, who in due course may expect to have at his command data sufficiently complete to enable him to give to the world a well-rounded story of the American race."

This permit comes very timely, for recently in Mexico some authentic geological and archeological explorations have, as they report, found data which calls for a "face about in archeology and history." It seems that a quarry had been opened up in an ancient flow of basaltic lava, and in the earth stratas below were found the remains of aboriginal life belonging to a very ancient culture. The age of the lava flow is established geologically at 5,000 years, and the indicated age of life previous to the eruption of the volcano Xitli is 2,000 years; making the

remains found at the lowest depth of the most primitive culture about 7,000 years old. These remains consist mostly of pottery, clay heads and figurines. The clay vessels are semi-globular, without much appearance of a neck, as though they were copies of holes in the ground, such as would be used in moulding the crude clay pots. The clay figures (fig. 2) of the lowest deposit are crude and grotesque beyond description.

The report states that they do not consider them to have been autochthonous, but that they arrived in Mexico probably by a northern route in the closing phases of the glacial epoch. Not considering them to have been native to the soil, and consequently not Paleolithic in the usual classification of peoples of that age of the world, they have selected a new appellation, calling them by the improvised name of To-achtopay-atlaca, meaning "our primitive people." This brings us back to a realization of a possible Paleolithic race in America, as ancient as any indicated in the Old World. Another interesting matter in the way of collecting archeological information is mentioned as follows: "Unfortunately although work has been carried on at the San Juan Teotihuacan pyramid for so long a period as 15 years, and a museum erected, it is reluctantly admitted that the material there is not arranged in scientific order, hardly any of the specimens having the place marked from which they were derived." This calls attention to the failure of noted specimens in the past to receive credit when they were apparently Paleolithic, but which were carelessly removed from their environment without data sufficiently accurate to permit a positive conclusion. A recent interesting find illustrates the case as follows: In a rock shelter, known locally as Jacob's Cavern, situated in the Ozark mountains in Missouri, there were found in April of last year (1921) a number of decorated bones, perforated as if used for a necklace. This cavern had previously furnished valuable specimens of aboriginal life when excavations were made for the Phillips Academy Museum some 20 years ago, and was a favorite resort for those who cared to dig for Indian relics. Mr. Taylor, the owner of the land and finder of the specimens in question, had from time to time dug further and further back, attempting to reach the extremity of the overhang. Stalagmites had formed in places and one of these had been shattered by a charge of dynamite without the owner's knowledge. In company with a friend Mr. Taylor happened to dig at the location of this stalagmite and unearthed nine specimens of perforated bone and shell. They were rudely ornamented with incised lines, one design having an outline suggesting the elephant (fig. 3) and two suggesting the deer. On exposure to the air the smaller bones soon crumbled and the larger ones were saved only by encasing in paraffin. Dr. Clark Wisler, of the American Museum, was asked to visit the premises, which he did in August, 1921. The results of his visit are given in a memorandum to Mr. Taylor as follows:

"The opportunity afforded me by your hospitality to examine the carved bone found by you and the privilege of exploring further in the cave, in the company of Mr. Randolph, Dr. Vernon C. Allison, and yourself, is greatly appreciated. Jacob's Cavern has long been known to us through the report of Peabody and Moorehead and has frequently been

cited as one of the possible type stations for early man in America. It is, therefore, of unusual interest to know that this site is by no means exhausted, but still rich in data. The question your find raises is whether the person who made the sketch on the bone which has been preserved saw a mastodon or mammoth. This cannot be answered positively, but the probabilities of the case can be estimated. In the first place, the work is of the primitive stamp and such as we might expect from the hand of an American native. It so happens that upon these bones at least three attempts were made to represent living forms, apparently by the same artist. Two of these forms have the distinctive lines of elk and deer, while the lines of the third characterize elephant kind. This favors the interpretation that an elephant, mastodon, or mammoth was intended. At once the objection will be raised that the bone is recent. Though the mastodon and the mammoth are characteristic of Pleistocene time, it is not known when they became extinct; for all that is known to the contrary, these great mammals may have

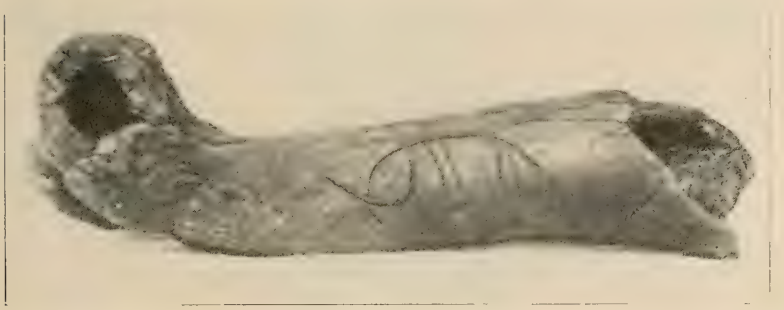


Fig. 3. Carved bone from Jacob's Cavern. Note carving representing a mastodon type of mammal.

held out to within three thousand years ago. Thus, the artist could have seen one of these animals and still have lived under modern conditions. No one in authority seems now prepared to deny that man was in America three thousand years ago. In other words, there is nothing zoölogical that makes your interpretation improbable. We must, therefore, turn to the cavern itself. It appears that this bone was found in the present surface of the cave, but approximately five feet of deposit were taken out by Moorehead in 1903; hence this bone is older than anything found by him. When we recall that both Peabody and Moorehead were impressed with the great age of what they removed, the evidence is again favorable to your interpretation. Also, there are still in the cavern almost five feet of deposit, in the main clay, through which you were so kind as to sink a shaft in my presence. This excavation indicated the presence of man's handiwork in all parts of this deposit, one piece of worked stone being found at the bottom of the shaft, lying flat upon the original stone floor of the cavern. One must conclude, therefore, that there are remains in the cavern that are of

greater age than the bone in question. In general, then, I regard this site as one of the most important yet discovered and one demanding further investigation. Regardless of what may ultimately prove to be the significance of this carved bone, you have made a discovery of great promise. I assure you of my appreciation of your confidence, in extending an invitation to make further excavations in this deposit and its surroundings. So, pending the examination of the site, as indicated above, no further comments seem necessary. The writer will do everything he can to further this investigation to the end that the complete story of Jacob's Cavern may be revealed. It is to be hoped that at last we are on the trail of early man in America."

Smithsonian bulletins have this to say on the subject in general: "Caves and rock shelters representing various periods and offering dwelling places to the tribes that have come and gone, may reasonably be expected to contain traces of the peoples of all periods of occupancy. Vast areas of limestone rocks of varying age occur in which are countless caves, the great caverns of Kentucky, Indiana, Virginia and Missouri being well known examples. It is observed that in general these caverns have existed for a long period, extending back well beyond the time when man is assumed to have appeared on the continent; but the deposits forming their floors, with few exceptions, have not been fully examined and up to the present time have furnished no very tangible evidence of the presence of man."

These meager results may possibly be accounted for by the fact that rare antiques have been and are expected as a reward for digging, delving and exploring. What an explorer should hope to find, if he is skilled, is something which will enable him to date and explain the site he is excavating, or the period to which it belongs. Regarded in that way, the intrinsic value and beauty of the objects found is irrelevant. This idea of archeological research applies forcibly to the work of determining the beginnings of aboriginal man in America, for the proofs are rare and Nature has buried them deep. Mexico has its volcanic lava flows which have preserved the records in stone; and other sections have lake dwellings with shell heaps in which traces of early man lie buried; but here in mid-continent the mounds and caverns must be looked to for ancient and unwritten information. Ohio has obtained a most enviable history in its mounds and earth embankments, but this is mainly in the way of remarkable achievements by the later cultures of that prehistoric Indian race. In no section probably is there a better field for research than in Indiana, for there is hardly a county in southern Indiana but what can show caves or rock shelters, and in some they are very numerous. It would not necessarily be a large cave that would be most desirable for habitation. and the Indiana Historical Commission in its work of developing a State Archeological and Historical Survey will probably be able to locate those which show signs of having been in such use.

Scattered over the length and breadth of the land in almost all directions are the innumerable conical mounds which vary in size and apparent use, some being of a sepulchral nature while others bear traces

of religious rites in which fire was made use of, and others bearing no trace of their real use. In the sepulchral mounds the objects buried with their various owners indicate the predominant traits of character of that people, being mostly the stone weapons for self-defense and the slate gorgets or charms of supposedly supernatural power. Of the weapons, most are of a flint nature, breaking with a splintery fracture and chipping to a sharp edge with a conchoidal fracture. The very first weapon, that of a spear head (fig. 4), is taken to be the first stone implement fashioned by man, and was done in a crude way,—simply a pointed stone of a shape which could be fastened to a shaft to form a

Fig. 4. Rude flint spearhead, Paleolithic type. Original.

spear. This marked his entry into the realm of investigation and art craft, and is taken to mark the latest phase of Paleolithic life. Following this came the multitude of artifacts marking the stages in Neolithic culture.

The spear or lance came early to hold a prominent place on ceremonial occasions, being suited for prominent display in processions and dances. Flint from which the spearhead was formed appears most abundantly in Ohio, Illinois and Indiana, and large aboriginal quarries were worked in the two former states. Kaolin, a clay desirable for pottery, also abounds in this territory, so that two things most conducive to growth in the earliest period were present, and the multitude

of mounds and earthworks are evidence of the presence of a third dominant feature, religious ceremony.

A large proportion of the conical mounds show no implements interred and no traces of burial, but the latter can be accounted for if an age of construction which could easily run into the thousands of years is conceded, in which time every vestige of bone even would have disappeared. The immense earth embankments at Fort Ancient in Ohio are conceded to belong to the earliest stage of aboriginal life which left visible traces of this kind behind them. Indiana shares with Ohio the landmarks so laboriously erected by this unknown race, for they lie on the outskirts of the territory marked by earth embankments of circular, square, elliptical and irregular outline which extends west along the southerly side of the great lakes into Indiana. Smithsonian bulletins say of them: "The Mound-builders seem to have skirted the southern border of Lake Erie and spread themselves, in diminished numbers, along the territory south of Lake Ontario, and penetrated into the state of New York as far as Onondaga where some slight vestiges of their work were found. These seem to have been their limits to the north-east. They extended in the same manner westward into Iowa and Nebraska, but no record is had of their occurrence above the great lakes. They are distinguished for their regularity, most of them being circular or square in form, and are found isolated and also in groups. They are mostly of a diameter of 250 to 300 feet and almost invariably have the ditch interior to the wall, and always have a single gateway. The enclosure was sacred and set apart as 'tabooed' or sacred ground."

In Wisconsin a wonderful profusion of earth embankments prevail and are radically different from those forming the chain along the territory south of the great lakes. They are mainly of two general outlines,—straight, linear embankments and those of animal and bird outlines, all of which are interspersed with conical mounds. The peculiar features of linear mounds are that while on an average of two or three feet in height, they begin with an increased height at one end and taper in width and height to almost a point at the other end; and, further, that in some cases they begin on a level plateau with the high portion and extend down the adjoining slope decreasing in size almost to a point. This latter feature is also found in some cases of irregularly shaped mounds and effigy outlines. The mounds are seldom over eight feet in height and the earth embankments are frequently only about two feet in height and often merely a trace. While the circular earth embankments of the great lakes region, as a whole, indicate an almost exclusive ceremonial use, those in Wisconsin go farther by representing living forms and probably were endowed with mythical life, and we are again reminded of the fact that the Indian was an "animist", to whom every animal and object in nature contained a spirit to be propitiated or appeased. Another feature peculiar to Wisconsin is the matter of so-called "Garden-beds." They are located in valleys and cover acres of ground in the form of ridges three to five feet apart, with a furrow between. They are parallel and are mostly straight but in some cases are broken by sections having parallel curved ridges or irregular

outlines similar to a turtle back. As a whole they resemble very closely the designs on pottery, particularly those reported from the Cahokia group of mounds in Illinois, across the Mississippi river from St. Louis. There may have been a relationship between these people who lived in the same river valley and made use of similar designs. The emblems on the pottery are understood to have had a mythical meaning, and these ridges are apparently of a ceremonial nature.

Referring again to the earth embankments in Indiana which form a part of the chain of earthworks stretching along the south side of the great lakes, the group at Anderson was described in the Geological report of Indiana for the year of 1878; and again in 1892 by F. A. Walker of Anderson, who read a paper at the annual meeting of the Indiana Academy of Science of that year, which was published in the Academy Proceedings, but without a copy of the photographs which

Fig. 5. Portion of circular embankment in Mounds Park at Anderson, Indiana. Photograph made by Mr. F. A. Walker in 1892. Original.

had been made. He had a survey made and described the group as consisting of seven structures of circular and oblong outline, the largest one being 360 feet in diameter, 1,131 feet in circumference, covering two and one-third acres. The maximum height of embankment is given as over 9 feet and accompanied by an interior ditch of about 12 feet maximum depth, and having an opening or gateway of 30 feet between ends of embankment. Mr. Walker took great pains to secure photographs of this embankment (fig. 5), and we take pleasure, after a thirty years interval, of seeing them again presented.

Another embankment, second in importance in Indiana, is at Strawtown in Hamilton county, northeast of Noblesville. We say second in importance, for while it is a single embankment instead of one of a group, yet at the same time is one of the noted exceptions in the way of construction, being one of the few having the ditch outside of the

embankment. It was reported in the Geological report of Indiana for the year of 1875 as being 280 feet interior diameter, the ditch being 30 feet in width and about 9 feet deep.

A third embankment is of a rectangular shape and located at Winchester in Randolph county, a portion of which was formerly within the county fair grounds. In the Geological Report of Indiana for the year 1878 it was reported as containing about 31 acres, the interior area being about one fourth mile in length and over a thousand feet in width. The embankment was 6 to 8 feet high with a gateway at each end, one of which had an elaborate entrance in the form of a crescent. It is remarkable as to outline and for having no ditch accompanying the embankment; also in having two gateways, inasmuch as Smithsonian descriptions say these single earthworks invariably have but one gateway.

Indiana is most fortunate in having these three groups or instances of aboriginal earthworks which may prove to be primeval. They are specially interesting as they represent three different types of construction and commemorate a remarkable race of primitive times and one with a personality which American history will be proud to record.

Of the use to which these earthworks were put, Smithsonian conclusions are as follows:

"On the whole, the American Indians incline strongly towards all forms of religious excitement. Their festivals and games were accompanied by religious rites, some being confined to groups and others participated in by whole tribes. Specially prepared lodges or grounds were tabooed, into which none but the initiated could enter, and which were indicated in such a manner that the public might not mistake it. The ceremonies formed intrinsic features and may be regarded as phases of culture, their special character depending on the state of culture of the people by which they were performed; hence there are at least as many kinds of ceremonies as there are phases of culture in North America."

As to segregating the phases of culture and working out a sequence, which has probably been awaiting the completion of sufficient exploration, it would seem practicable to draw the same line in the stone age that is done in Europe, viz. the early or primitive stage as separate from the later or perfected stage. As flint may be taken as emblematic of the early period, being the material so easily fractured into the form of a spearhead, so may we select the stone of hard and tough texture, such an granite, syenite, diorite, basalt, etc., as typifying the late period in the stone age. This tough, grained rock was subject to abrasive treatment in the way of hammering, pecking and rubbing to give a desired outline and cutting edge. The first implement in this line to be worked out has been considered to be the hatchet shaped implement known as the "celt" (fig. 6) which appears in about the same form in the stone age of European countries. It required long and patient work to give it the required outline, and then the cutting edge was formed by a rubbing or polishing process, and this polishing in some cases was applied to the entire surface of the implement.

Fig. 6. Celt of smoothed stone, Neolithic type. Original.

The line between the two stages of aboriginal life in the stone age, known as the early and late, is well drawn by the Encyclopedia Americana, 1920 edition, as follows:

"The art of polishing stone implements was introduced near the beginning of the Neolithic period. It is on this basis,—the absence of polished stone implements in the deposits of the Old Stone Age and their presence in those of the young Stone age,—that the names Paleolithic and Neolithic are given."

RECENT ARCHEOLOGICAL DISCOVERIES IN JEFFERSON COUNTY, INDIANA.

GLENN CULBERTSON, Hanover College.

During the year 1922, some further investigations were made into the archeology of Jefferson County. One result of this work was the discovery of an additional mound, located along the bank of the Ohio River, approximately one mile above the mouth of Indian Kentucky creek in Milton Township, near the middle of section seven, on the Coleman farm. This mound is on what is locally known as the second bottom, or first terrace, and had been so undercut by the waves of the Ohio River during recent floods, that at least half of it had fallen away. The remnant indicated that the original mound had been 75 or 80 feet in length and 40 or 50 feet in width.

Near the middle of the mound lengthwise, and at a depth of some two and a half feet below the present surface, the writer found exposed where the bank had fallen away, a complete human skeleton lying at full length. The bones were much decayed, being, in that respect, very similar to those taken from the Lawson mound, a few miles away, some 20 years ago. Several parts of the skull, one clavicle, one humerous, a few vertebrae, the head of the left femur, and two teeth, incisors, were obtained in a fair state of preservation. Measurements of the remains indicated the height of the person to have been somewhat over six feet. The right humerus measured exactly 14½ inches in length, and one of the finger bones also indicated a person of rather unusual height. The bones of this skeleton are at present in the geological museum of Hanover College.

At the same level as the skeleton, which was that of the base of the mound, were found many fragments of Ordovician limestone partially burned and badly decomposed, a few fragments of river mussel shells, and several fragments of very hard river boulders and pebbles of glacial origin. Since it is very difficult to break these boulders even with a heavy hammer, the probabilities are that these had been broken by heating to a red heat and then plunging into a vessel of cold water in cooking or other operations. No implements of stone were found closely associated with the skeleton, but many arrow heads, tomahawks, pestles, polished fleshers, and other such articles have been, and are still being picked up from the surrounding bottom lands. Judging from the number of implements found, and fragments of chert and of flint to be seen in the vicinity for several hundred yards from the mound, this site was probably that of a village. Flint such as may be picked up at this place is not found in any geological formation within many miles.

Another recent discovery of archeological interest in Jefferson County was that of a cache or deposit of flint implements. This cache was found early in 1922, on the farm of Hiram Foster in Graham Township, in the northeast quarter of Section 15, Township 4 North, and Range 9 East, some 300 yards from the old Hartwell mill site on Big creek. The immediate location of the deposit was a clay point

"Proc. 38th Meeting, 1922 (1923)."

from which one or more feet of soil had been removed by erosion. There is no evidence of the deposit having been made in a mound or in connection with an unusual structure. Ninety implements were taken from this cache, all of which, except one, were in perfect condition. A few of the implements had been exposed by erosion, the others were obtained from a space not more than a foot or so across. Some 70 of these implements were in the possession of Mr. Foster, and others had been sold by the party who had removed them from the cache. Mr. Foster kindly donated six typical specimens to the geological museum of Hanover College. The implements of this deposit are composed of pure flint, and are remarkably uniform in shape. They are ovate in outline, varying in length from five to ten inches, in breadth from three to six inches and in thickness from three-eighths to five-eighths inch. All were finished entirely around the edges very much as an ordinary arrow or lance head. They were made of flint and are therefore quite dark in color. Circular and oval markings on the greater number of them show that they were made from flint concretions. The source of these concretions was not local, but probably from the Mississippian limestone of Harrison and Crawford Counties.

The purpose for which these implements were manufactured is largely conjectural. Some consider them to have been made for spades or hoes. If it were not for their evidently finished condition, they might be considered as material in course of preparation for arrow or lance heads. Neither theory as to their use is satisfactory.

The writer wishes to suggest that, in making the proposed archeological surveys of the different counties in Indiana, the implements found in each county, be placed in county, state, or institutional collections. In Jefferson County almost every farm house contains a few implements, but there is no one very large collection. If all specimens from a county could be placed in one group, properly labeled, and the name of the owner, and the locality in which the collection was made, attached, county collections of great interest and value could be accumulated.

ARCHEOLOGY IN POSEY AND VANDERBURGH COUNTIES.

A. J. Bigney, Evansville College.

Posey County is located in the extreme southwestern corner of Indiana, bounded on the west by the Wabash River and on the South by the Ohio River. The county has broad, low bottoms along these rivers, rising gently toward the interior, with numerous hills breaking the general level of the county. More than twenty lakes dot its surface, Hovey Lake, which is circular and about one mile in diameter, being the largest.

Vanderburgh County lies directly east of Posey County and is much smaller. Low bottoms several miles wide border the Ohio River, and the country rises gently into the hills and higher land in the center and northern part of the county. West of Evansville these hills approach the Ohio River.

The natural location of this section of the state seemed to have made it attractive to the earliest known inhabitants, the Mound Builders, later the Indians, and finally the white man. The New Harmony movement had its rise, development and failure in the western part of this territory, at the town of New Harmony. Even Audubon and Say found this an interesting and fruitful locality to study birds and insects.

In Posey County there are four mounds west of Mt. Vernon, not far from the river, but on high ground. In the eastern part of Vanderburgh County there are five mounds of considerable size. The only mound away from the river is found about twelve miles north of the Ohio. It has been largely explored and most of it has disappeared. These mounds have been more or less completely explored and the specimens distributed to many parts of the United States, the Smithsonian Institution having secured many of them. In the Museum at New Harmony large numbers of these relics have been placed and are now exhibited to the public. Last year a Museum Society was organized and incorporated in Evansville to receive a large collection from Sebastian Henrich. This collection, which is entirely local and made by Mr. Henrich, has been arranged and placed on exhibition in rooms in the Willard Library in Evansville. It consists of about 2,000 arrow points of great variety, and many of them the finest I have seen, a large number of drills, besides some good pieces of pottery, many splendid pipes, hundreds of celts, axes and copper specimens.

Another similar collection was made by C. F. Artes of Evansville. After his death it was sold for $7,500 and removed from the city. A third collection, now consisting of about 5,000 specimens, half of which are arrow points, is owned by Mr. Otto Laval, who lives five miles east of the city of Evansville. His collection of drills is the best that has been made in this section. The mortars or grinding stones are of rare patterns, one being eighteen inches in diameter. One has an oval concavity and a pestle ground to fit it. His copper specimens, one of which

"Proc. 38th Meeting, 1922 (1923)."

is a helmet, are superior. The collection of pipes is also very good, as well as the minerals, axes, celts, and a large variety of pottery.

In addition to these large collections, many smaller ones have been made in an incidental way. New specimens are being found from time to time. Last year a very peculiar one was found ten miles east of Evansville near the mouth of Green River by a negro while digging a hole in which to bury a dead animal. This specimen (fig. 1) which is

Fig. 1. Indian pipe taken from a mound near Evansville, Indiana. About one-half natural size.

recognized by the Smithsonian authorities as a pipe, is six inches high and seven inches long, and is made of light gray sandstone. It represents a man on all fours with head raised, and has two conical holes in it, one on the back and one in the rear—the two holes connecting. One hole served as the bowl and the other for the attachment of the stem. Having been found in the alluvial deposit, it indicates that it had been washed there. In the locality where this pipe was found are the five mounds of Vanderburgh County referred to above, and it seems highly probable that it came from one of these, either directly or from some house where it had been kept as a relic after having been taken from a mound.

Not only are works of man found in Posey and Vanderburgh counties, but also the remains of some of the ancient animals as well. A few weeks ago a part of the tooth of a mastodon was found in the river at West Franklin, 12 miles below Evansville. Near the same place, not long since, a thigh bone was found which weighed 55 pounds.

GONIOBASIS LIVESCENS MENKE, A PLEISTOCENE SHELL IN FURNESSVILLE BLOWOUT, DUNES OF PORTER COUNTY.

MARCUS WARD LYON, JR., South Bend.

On the floor of the Furnessville Blowout[1] is a comparatively large bed of small, white, and somewhat weather-worn univalve shells. Closely associated with them are flat, rounded, water-worn small stones like those that are so frequently found at the low water edge of the lake.

Fig. 1. *Goniobasis livescens* on the floor of Furnessville Blowout. The small white objects in the foreground are the shells. In the distance are some low fore dunes just beyond which is Lake Michigan.

In 1921 a small handful of these shells was picked up and sent to Dr. Paul Bartsch of the United States National Museum. They were identified as *Goniobasis livescens* Menke of Pleistocene Age. Dr. Bartsch suggested that the place where they are found possibly represents an old shore line. With reference to the present shore line and level of Lake Michigan this open bed of shells is found about 150 yards south of the present shore and about 15 feet above the present level of the lake. (Fig. 1.) It lies immediately back of a line of low fore dunes.

[1] On the shore of Lake Michigan, opposite Furnessville station of the Chicago, Lake Shore and South Bend Railway.

"Proc. 38th Meeting, 1922 (1923)."

In the absence of figures of actual surveys the impression is that the floor of the Furnessville Blowout is probably lower than the floors of other blowouts in the region and also that it is approximately the same height as the low ground between the dunes and the tracks of the Chicago, Lake Shore and South Bend Railway. Although I have been in many of the blowouts in this region, between Michigan City and Oak Hill, the one designated as Furnessville is the only one in which I have found these shells.

No opinion is ventured as to the significance of these shells at the place indicated.

A REVIEW OF THE PRESENT KNOWLEDGE OF FOSSIL SCORPIONS WITH THE DESCRIPTION OF A NEW SPECIES FROM THE POTTSVILLE FORMATION OF CLAY COUNTY, INDIANA.[1]

By John Irwin Moore, Owensville.

The following paper is a condensed review of the literature on fossil scorpions with the description of a new species from the Pottsville formation of Clay County, Indiana.

Interest in Fossil Scorpions. Wide interest in fossil scorpions was first aroused by the discovery of a specimen in the Silurian rocks of Sweden which was first made known to the Swedish Academy of Sciences, on November 12, 1884. The fact that this "apparently carried the history of air-breathing or land animals much further back in geological time than had hitherto been known"[2] was enough in itself to attract wide interest. A published statement of the Swedish find first appeared in Comptes Rendu of the French Academy, Dec. 1, 1884. This was closely followed by an announcement of the discovery of a specimen in the Silurian rocks of Scotland, published in the Glasgow Herald, Dec. 19, 1884. Almost a year later (Oct. 10, 1885) a similar find was announced from the Water-Lime beds of New York (Silurian). This almost simultaneous discovery of rare and peculiar fossils caused accounts of them to be published in many scientific and popular journals.

Their Bearing on Geological History. At present fossil remains of scorpions have been described from the Silurian and Carboniferous, and from amber deposits of Oligocene Age. According to Fritsch[3] the order Scorpionida attained its acme during the Carboniferous and subsequently declined.

As stated above the Silurian scorpions constitute the earliest suggestion of land or air-breathing animals, but Whitfield, concludes that they could not have been air-breathers but were wholly aquatic and that their descendants acquired the terrestrial habit in subsequent generations. Pocock has suggested that the supposed mesosomatic "sternites" of Palaeaphonus are really broadly laminate gill-bearing appendages, as they have been shown to be in Eurypterus[4]. Similar appendages occur in the Carboniferous Genus Eobuthus, and it is inferred that respiratory lamellae lay beneath them as they do in Limilus[5]. Many writers have expressed the belief in the origin of the scorpions from the eurypterids and this has been used in the development of a theory for

[1] To Professor Stuart Weller I wish to express my thanks for many valuable suggestions and for his encouragement in attempting the study and description of the specimen. From my brother Prentiss D. Moore I received much assistance in the preparation of the photographs. Greatest thanks are due Arch Addington of Indiana University, who saved the specimen for description.

[2] R. P. Whitfield—On a Fossil Scorpion from the Silurian Rocks of North America. Bull. Amer. Mus. Nat. Hist., Vol. I.

[3] Zittel—Text Book of Paleontology.

[4] Clarke and Ruedeman—New York Geol. Sur.

[5] Zittel—Text Book of Paleontology, p. 788.

"Proc. 38th Meeting, 1922 (1923)."

the origin of the vertebrates which is discussed at length by Patten[6] and Gaskell[7].

Present State of the Knowledge on Fossil Scorpions. Petrunkevitch[8] also thinks the Water-Lime specimen must have been a marine form, and here it might be well to add a few words on the conclusions reached in his study of the phylogenetic development of the scorpions. He says: "That the different classes of arthropods must have developed not from one ancestor but at different times and from different species of chaetopodous worms;" that the scorpions no farther back than Carboniferous times were not equipped with internal lung books and in the structure of these parts they do not resemble the eurypterids as was suggested by Pocock; that eurypterids have in some respects closer relations with limuloids than with scorpions; that the Bertie water-lime, which contains the eurypterid having the closest resemblance to scorpions, also contains the oldest true American scorpion; and finally, that the Xiphosura, Eurypterida and scorpions developed independently and that the great similarity is due to convergence as Thorell suggested. Some have suggested that the different sub-classes "must have been differentiated even in Pre-Cambric times[9]." The well preserved specimens from the Oligocene indicate that the scorpions then had practically the same habits as they possess today. Schuchert[10], in his discussion of the Silurian forms, after summing up the evidence, concludes that they were semi-aquatic, living along the shore, above the Strandline, feeding on small crustaceans and other small invertebrates.

Fossil Carboniferous Scorpions. The Carboniferous scorpions have been extensively treated, by Fritsch in continental Europe, Pocock in England and Petrunkevitch in North America. Petrunkevitch in describing the 16 available specimens from North America placed them in ten species, six genera and four families. The likeness between some of the Carboniferous forms and the recent forms is very striking.

Present State of Classification of the Order. Each one of the workers in this field has arrived at a different conclusion as to the classification of the order; so I will here give a brief summary of the existing state of the classification.

The Classification of Karsch. Karsch[11] divided the order into four genera, *Eoscorpius, Microlabis, Cyclaphthalmus* and *Mazonia.* In his classification *Eoscorpius* Meek and Worthen contained: *Anglicus,* Woodward and *Carbonarius,* Meek and Worthen. *Microlabis* Corda, contained the species *sternbergii* Corda. *Cyclophthalmus* Corda, contained the species *senior* Corda. *Mazonia* Meek and Worthen, contained the species *woodiana* Meek and Worthen.

Work of Scudder and His Classification. Scudder[12] in his work two years later recognized only three genera placing all of them in the

[6] Patten—The Evolution of the Vertebrates and Their Kin.
[7] Gaskell—The Origin of the Vertebrates.
[8] Petrunkevitch—Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.
[9] Petrunkevitch—Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.
[10] Schuchert—Textbook of Geology, Vol. II.
[11] Karsch, F. E.—Zeitschr. deutsch. Geol. Ges. (1882), pp. 556-561.
[12] Scudder, S. H.—Proc. Amer. Acad. Arts and Sciences, Vol. XX, 1884, pp. 15-22.

family Eoscorpionidae. He considered the genus *Microlabis* as synonymous with *Cyclophthalmus*. In the genus *Eoscorpius* Meek and Worthen, he placed *carbonarius* Meek and Worthen, *anglicus* Woodward, *euglyptus*, *glaber*, *inflatus* and *tuberculatus* Peach. The genus *Cyclophthalmus* contained *sternbergii* and *senior* Corda.

Hasse's Redivision of the Order. Hasse[13] redivided the order Scorpiones with respect to the true scorpions, into the sub-order Anthracoscorpii, family Eoscorpionidae and sub-families Eoscorpionini and Cyclophthalmi.

Fritsch in Continental Europe. Under the order Scorpiones, Fritsch[14] recognized the sub-order Dionychopades and family Anthracoscorpii, which he divided in seven genera. To the four genera,—*Eoscorpius* Meek and Worthen, *Microlabis* Corda, *Cyclophthalmus* Corda, and *Mazonia* Meek and Worthen, recognized by Karsch, he adds three new genera and two new species from material mainly undescribed. These new genera and species are as follows: *Isobuthus kralupensis* (Thorell and Lindstrom), *Eobuthus rakovnicensis* and *Feistmantelia ornata*.

Pocock in England. In his monograph on the English forms, Pocock[15] made some radical revisions of the classification. He first divided the order Scorpiones (other than Silurian) into two divisions, the Lobosterni, and the Orthosterni. The Lobosterni contained those forms having bilobed, posteriorly-laminate sternal plates on the opisthosoma and skeletal plates on each side of the genital operculum. In the division Lobosterni, he placed the genus *Eobuthus* of Fritsch to which he assigns a single species *holti*, a very fragmentary specimen, from the Shipley Clay pits. Pocock also thought *Isobuthus* of Fritsch might be assigned to the same group. The division *Orthosterni* contains the genera *Archaeoctonus*, *Cyclophthalmus* and *Anthracoscorpio*. To *Archaecctonus* Pocock, he assigned *Eoscorpius glaber* Peach, and *E. tuberculatus* Peach. In the genus *Cyclopthalmus* Corda, he placed the species *Eoscorpius euglyptus* Peach. In the genus *Anthracoscorpio* he placed *Eoscorpius sparthensis* (Baldwin and Sutcliffe) and added two new species, *dunlapi* and *buthiformis*.

Late Revision of the American Species by Petrunkevitch. In America Petrunkevitch[16] has revised the entire Class Arachnida. In his work on the scorpions he was able to bring together all the then known specimens for re-examination. He divided the order Scorpiones into two sub-orders, the Apoxypoda containing the Silurian forms and the Dionychopoda containing the Carboniferous forms. In the sub-order Dionychopoda he recognized four families, 12 genera and 23 species, of which six genera with nine species are restricted to Europe, and five genera with six species are restricted to America. The genus *Eoscorpius*, regarded by Pocock as unsound, is accepted by Petrunkevitch. To it he

[13] Hasse, E.—Zeitsch. deutsch. Geol. Ges. 1890, pp. 629-657.

[14] Fritsch, A.—Palaeozoische Arachniden, 1904, Prague pp. 5-80.

[15] Pocock, R. I.—Monograph of the Carboniferous Arachnida of Great Britain, Pal. Soc.

[16] Petrunkevitch, A.—Monograph of the Carboniferous Arachnida of North America, Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.

assigns eight species, four occurring in Europe and four in America. No species are found to be common to both continents. From these facts Petrunkevitch drew the two following conclusions: (1) "that the Carboniferous arachnological fauna of North America is distinct from that of Europe and developed along somewhat different lines," and (2) "that both faunas have more similarity with recent faunas of tropical countries, than with such of the same locality."[17] The following outline brings out Petrunkevitch's classification very clearly:

Order *Scorpiones.*

"Head completely fused with the thorax. Abdomen twelve-jointed, the last five somites forming the so-called cauda or post abdomen, considerably narrower than the anterior seven. Telson with a poison gland and sting. Chelicerae three jointed, chelate. Pedipalpi six-jointed, chelate, powerful. Coxae of first and second pair of legs with maxillary lobes. Abdominal tergites and sternites heavily chitinized connected laterally with each other by means of a soft chitinous cuticle capable of considerable distension. Post abdominal segments without pleural membranes, their sternites and tergites completely fused in each segment. First sternite represented by the genital opercula, second sternite by the basal joint of the comb. Four pairs of stigmata leading to lung-books in third to sixth sternites, one pair to each sternite. Anus without operculum at the end of the twelfth abdominal segment, ventral to the poison gland. Two middle eyes and two to five pairs of side eyes on cephalothorax, some recent species completely blind. All recent scorpions are viviparous."

Sub-order—*Apoxydopa* (Silurian).

Tarsi terminating in a sharp point, without claws.

Family *Palaeophonidae* (T. & L. 1884).

Genus *Palaeophonus* (3 species, all European.)

Genus *Proscorpius* (1 species, American.)

Sub-order—*Dionychopoda.*

Scorpions with two claws at the end of each tarsus (includes Pocock's Lobosterni and Opisthosoma). The families of this sub-order are based on the structure of the coxae and not upon the shape of the abdominal sternites.

Family *Isobuthidae.* Coxae of the fourth pair of legs abutting against the genital opercula.

Genus *Isobuthus* (1 species, European).

Genus *Eobuthus* (2 species, European).

Genus *Palaeabuthus* (1 species, American).

Family *Cyclophthalmidae.* Normal arrangement of coxae, sternum pear-shaped.

Genus *Cyclophthalmus* Corda, 1835 (2 species, European).

Genus *Palaeomachus* Pocock, 1911 (2 species, European).

Genus *Archaeoctonus* Pocock, 1911 (1 species, European).

[17] Petrunkevitch, A.—Monograph of the Terrestrial Paleozoic Arach. of North America, Trans. Conn. Acad. of Arts and Sci., Vol. 18, p. 28.

Family *Cyclophthalmidae*
Genus *Eoctonus Petrunkevitch* (1 species, American).

Family *Eoscorpionidae.*
Normal arrangement of coxae, pentagonal sternum.
Genus *Eoscorpius* Meek and Worthen, 1868, (8 species, 4 American and 4 European).
Genus *Trigonoscorpio* (1 species, American).
Genus *Palaeopisthacanthus* (2 species, American).
Genus *Microlabis* Corda, 1839 (1 species, European).

Family *Mazonidae.*
Middle eyes close to anterior edge of cephalothorax. Structure of pedipalpi and sternum unknown.
Genus *Mazonia* Meek and Worthen, 1868 (1 species, American).

The classification proposed by Petrunkevitch has the advantage that it is based on characters ascertainable even from fossil specimens, although derived from the comparative anatomy of recent forms. This classification will be followed as closely as possible in the description of the specimen in hand.

Comparison of Fossil Scorpions to Modern Forms. In the comparison of most fossil organisms with living forms usually only the broader features can be considered, for the finer generic and specific characters upon which modern forms are differentiated are commonly lacking to a greater or less degree. This condition is met with among the Paleozoic scorpions. The general morphology of scorpions has changed but little since Silurian times, the greatest modifications being in the structrue of the legs and feet and the much debated breathing apparatus. It has been suggested by some authors, after a comparison of the shape of the bodies of some fossil scorpions, that the viviparous habit was acquired before Carboniferous times. These characters may have followed as a result of the change from an aquatic to a terrestrial habitat.

Brief Notes on the Morphology of Modern Forms.—Only the external characters with which this paper is concerned, will be considered here.

Scorpions are animals with a segmented chitinous exterior skeleton, the anterior segments of which are fused to form the cephalothorax. The praeabdomen is composed of seven broad, thick, movable segments which surround the principal viscera. A prolonged extension of the praeabdomen, consisting of five segments, is known as the postabdomen. The last segment of the postabdomen is armed with a stout curved spine which bears at its extremity the opening of two ducts leading from a pair of glands lying in the twelfth abdominal segment and secreting a poisonous fluid.

The first pair of appendages are called the chilicirae and are situated in front of the mouth. These appendages are chelate. The next pair of appendages are the strongest appendages and are provided with chelae. Their chief service is in grasping and bringing food to the mouth. The coxae of the second, third and fourth pairs of appendages are situated about the mouth and serve as jaws. Behind the pedipalps

are four more pairs of appendages, the six-jointed walking legs. The abdomen is also supplied with modified appendages. The first segment of the praeabdomen probably bears the genital opening. The second abdominal segment bears a pair of appendages called the pectines, or so-called combs whose function is not very well understood. The ventral surfaces of the third to sixth abdominal segments, inclusive, bears each a pair of stigmata, the exterior openings to the lung-books which are the respiratory apparatus.

The eyes are situated on the dorsal surface of the cephalothorax and vary from two to six in number. One pair of eyes are larger and are situated near the median line. The others which are smaller are lateral. Some of the modern forms are blind.

Scorpions are viviparous, the genital orifice occupying the same position in both sexes.[16]

The Indiana Specimen. The specimen here under discussion was secured by Arch R. Addington in Clay County, Indiana, while serving in the capacity of assistant to the State Geologist. Mr. Addington recognized the importance of the fossil and later presented it to P. D. Moore, who in turn placed it in my hands for study and description.

Condition of the Specimen. The specimen was collected in a clay pit which had been opened in a shale member of the Pottsville formation. The specimen lying with its dorsal surface exposed is not an impression only in the soft shale, but it preserves the exoskeleton in the form of a thin, brown, chitinous film. The preservation of the specimen is excellent except that most of the terminal segments of the walking legs are missing and the fourth and fifth joints of the postabdomen are badly crushed. The left pedipalp is crushed back on the tip joints of the first left walking leg. The preservation of the remainder of the specimen will be considered as each part is taken up for description.

Geological Position. The specimen was found in a shale member of the Pottsville formation, in the basal portion of the Carboniferous series, of Clay County, Indiana. The Pottsville formation in Indiana consists of a series of sandstones and shales interspersed with coal seams. One thin lime-stone is present overlying the lower Minshall coal located in the upper or Brazil portion of the series. The Pottsville outcrop in Indiana has a northwest southeast trend upon the western side of the Kankakee branch of the Cincinnati arch, extending from Benton County on the northwest to Perry County on the Ohio River, Clay County being near the middle of the area. The general dip of the strata is to the southwest passing beneath the younger Pennsylvanian formations.

Zoölogical Relations of the Species. The preliminary examination of the specimen and the comparison with the descriptions and illustrations of the other American forms showed that it was a member of a genus previously unknown in America. Its characters at once suggested its affinity was with the European genus *Eobuthus* and continued study

[16] For further discussion on the morphology consult J. Playfair McMurrich—Textbook of Invertebrate Morphology.

has confirmed its reference to this genus, which becomes the second genus of the Paleozoic scorpions to have representatives on the two continents.

Eobuthus pottsvillensis n. sp. (Plate II. figs. 1, 2, 3, and 4.)

This species is represented by a single specimen, the ventral surface of which is exposed. Since all the other known examples of this genus also preserve the ventral side, satisfactory comparisons can be made.

The measurements of the specimen are as follows:

Total length—37.6 mm.
Length of tail—16.7 mm.
Length of first joint of tail—3.1 mm.
Length of second joint of tail—3.8 mm.
Width of next to last segment of abdomen—8.8 mm.
Length of chela—9.4 mm.

The structure of the cephalothorax is indeterminable due to the condition of fossilization.

The shape of the praeabdomen is an elongate oval. The sternum is clearly oval or sub-oval in outline. In shape it is closely similar to the British and Bohemian specimens except that the sternum of the latter specimens seems larger in proportion. The bilobed shape of the third, fourth and fifth sternal plates is very striking, and they seem to overlap in shingle fashion. No traces of stigmata can be observed even when examined under the high power binocular. The sixth praeabdominal segment curves in a convex line and joins the postabdomen, whose first segment is about one-half the width of this last segment.

The first two segments of the postabdomen are well preserved and show the keel structure in a remarkable degree. The third joint of this division of the body is partly destroyed, but the general size and shape of the first three segments are about the same. The fourth and fifth joints are badly crushed and lost and their outlines can barely be determined. The telson or poison sting is well preserved and lies deeper in the matrix and to the left of the main trend of the tail, this being the first specimen of the genus which has this part of the body preserved.

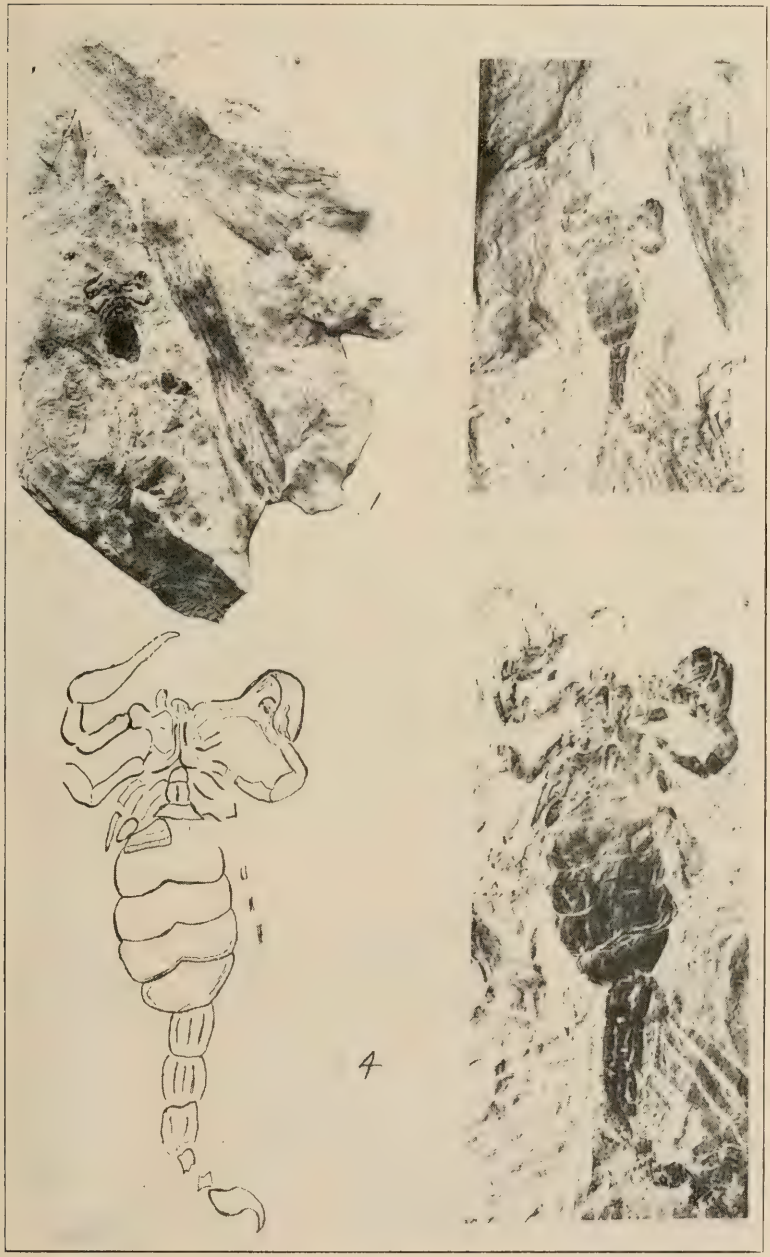
The appendages are as follows:

The outline only of the chelicerae is determinable. The right one stands out in advance much farther than the left. Their chelate structure can only be inferred.

The right pedipalp is fairly well preserved, the left one being crushed back on the tips of the first left walking legs. In comparison with other specimens these appendages are moderate in size only. The chela of the right pedipalp is preserved in an edgewise condition which gives it a very slender appearance. The position and length of the movable finger cannot be determined.

Only the coxae of the first pair of walking legs are preserved and the position of these seems to be normal. More of the second pair of walking legs is preserved than of any of the others. The right second walking leg is only preserved to the third joint which is

Plate I. Figs. 1 and 2, *Eobuthus rakovnicensis*, the figure 1 being a restoration by Fritsch from the genotype. (Fig. 1: 1, chelicerae; 2, coxae of pedipalps; c, coxae of second walking legs; b, basal plate of pectines.) Figs. 3 and 6, *Anthracoscorpio sparthensis*. Fig. 4, *Eobuthus holti*, found in the coal measures at Sparth, near Rochdale, England. Fig. 5, line drawing of figure 4 (after Pocock); *cx*. coxae of third leg, *g*. genital operculum, *pect*. one of the pectines, *scl*. schlerites abutting genital operculum, *st*. 3 to *st*. 7 third to seventh somites of opisthosoma.



Plates II. *Eobuthus pottsvillensis* n. sp. 1, condition when discovered; 2, as it appeared when the postabdomen had been uncovered (slightly less than natural size); 3, enlargement of 2; 4, line drawing to bring out structure.

club shape in outline, probably due to flattening in fossilization. The tip joints of the left second walking leg seem to be preserved but they are in contact with the crushed left pedipalp and their outlines are difficult to distinguish. Only the first two joints of the third and fourth pairs of walking legs are preserved. The coxae of the third pair seem to be situated a little more anterior than the coxae in *E. holti* although all the coxae resemble *E. holti* more than *E. rakovnicensis*. The basal joints of the fourth pair of legs abut against the genital operculum. These are the skeletal plates referred to by Pocock, about whose function he was in doubt. The Indiana specimen clearly shows that these belong to the fourth walking legs.

One pectine is very well preserved and the other one very faintly. Its structure as well as its plate of attachment is essentially similar to that in *E. holti*. The plate of attachment is roughly pentagonal in outline.

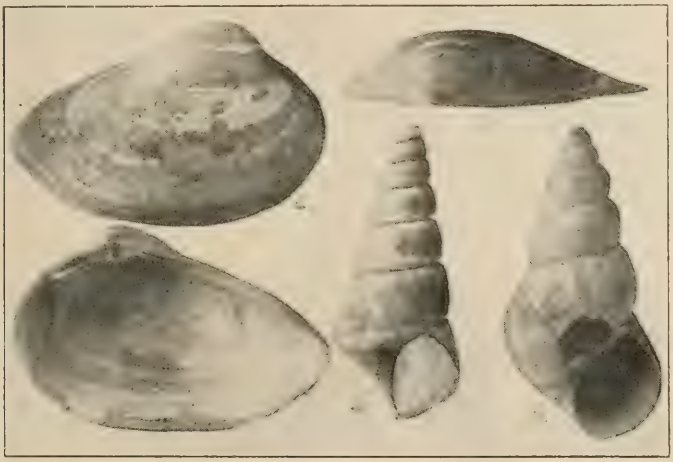
No trace of the stigmata has been detected.

General Observations and Comparisons. This specimen is better preserved than either of the other two specimens assigned to the genus. It exhibits all features except the dorsal surface and the extreme tips of the walking legs. Its closest relation is with *E. holti* (Pl. I, figs. 4 and 5) rather than with the genotype, but it differs from the single known fragmentary specimen *E. holti* in the shape of the pracabdomen and the position of the coxae, with also the probable difference in the ratio of the size of the sternum. It differs from *E. rakovnicencis* (Pl. I, figs. 1 and 2), the genotype, in the shape and length of the pedipalpi, and in the shape of the coxae and pectine. The absence of stigmata and the structure of the sternites suggests that these forms were not air-breathers but possessed respiratory organs similar to Limulus.

THREE NEW BRACKISH-WATER PLIOCENE MOLLUSCA FROM LOUISIANA.

ERNEST RICE SMITH, DePauw University.

In a paper published in the Proceedings of the United States National Museum, Vol. 46, pp. 225-237, W. H. Dall listed a considerable brackish-water Pliocene fauna, including many new species from the Atlantic and Gulf Coastal Plains of the United States. Outcrops of this horizon are found at intervals from the Satilla River, Georgia, to Newton County, Texas. One locality, which yielded him a very considerable fauna, was the Frank Muse Place, six or eight miles southwest of Alexandria, Louisiana.



Figs. 1, 2, and 3, *Mulinia harrisi* n. sp.; fig. 4, *Paludestrina dalli* n. sp.; fig. 5, *P. olssoni* n. sp.

In 1916, Professor G. D. Harris of Cornell University, made a small collection in a well, about thirty feet below the surface, on the Hunting Club grounds ten miles southwest of Alexandria. This material, washed and sorted, furnished twenty-one molluscan species, seven being Pelecypods and fourteen Gasteropods. The elements, believed to be new, consist of the three species here described as new and an imperfectly preserved Gasteropod, kindly examined by Mr. Dall who determined it as probably a *Melaraphe* Mühlfeldt. I wish to express my appreciation to Professor Harris for the opportunity to study this material and to Mr. Dall for his examination of the material believed by me to be undescribed.

Mulinia harrisi n. sp. Figs. 1, 2, 3.

This species resembles *Mulinia sapotilla* Dall and was confused with that species, because of inadequate material, in the paper mentioned above. It may be separated from that species by its deeper and better

"Proc. 38th Meeting, 1922 (1923)."

defined sinus, by its somewhat more slender form vertically and by its slightly greater globosity. Mr. Dall confirmed my opinion of the distinctness of this form by comparision with the original of his *M. sapotilla*, replying as follows: "The *Mulinia* which you sent agrees exactly with the specimen from the Pliocene of the Satilla River, Georgia, which I identified with my *M. sapotilla* from the Shell Creek Pliocene of Florida. After a comparison with yours, the differences seem constant." The same species probably occurred in the material which Dall had from the Frank Muse Place, but he did not compare my specimen with that material. The illustration, in the reference referred to above, seems to me to be *M. harrisi*, without question.

The type is a right valve in the Harris Collection, Department of Geology, Cornell University, Locality 134.

Length 15.8 mm.; height, 10.4 mm.; length in front of median line through the beak, 5 mm.: length behind the median line, 10.8 mm.; thickness, 3.4 mm.

Paludestrina dalli n. sp. Fig. 4.

Six smooth whorls; no umbilicus nor umbilical chink; whorls slightly flattened, angularly shouldered just below the suture; mouth slightly extended anteriorly in a somewhat flattened lip, departing from oval shape due to this extension, the flattening and the slight sutural shoulder; apex small, blunt. The mouth of the type is not entire, so it is impossible to say whether the peristome is thickened or not.

Length, 5 mm.; width, 2.1 mm.

The type is in the Harris Collection, Cornell University.

Paludestrina olssoni n. sp. Fig. 5.

Six smooth, evenly tapering, somewhat convex, unshouldered whorls; very small umbilical chink; apex acute; peristome unthicknened, oval.

Length, 4.35 mm.; width, 2.13 mm.

This species is named for my friend, Mr. Axel Olsson.

The type is in the Harris Collection, Cornell University.

QUALITATIVE ANALYSIS—TIN GROUP.

RALPH W. HUFFERD, DePauw University.

Numerous complaints from students that their results in the analysis of the tin division were not clear-cut caused the writer to investigate the matter. Two difficulties were found with the method generally employed. The first was in separating the tin group from the copper group, where care in avoiding solution of the latter led to incomplete solution of the former. The second was in separating tin and antimony from arsenic where appreciable amounts of arsenic sulphide dissolved to cause trouble later on.

Since it is generally necessary to remove traces of copper and mercury from the tin group precipitate, it was decided to make the treatment with polysulphide so severe that this procedure would become the rule. This would insure complete separation of the two divisions.

A somewhat similar decision was made in the case of the second part of the problem. It was decided to heat the reprecipitated tin group sulphides with 12N HCl at the temperature of boiling water since it is a simple matter to remove the arsenic sulphide which dissolves.

In order to avoid the difficulty which students have with the use of test-lead in reducing tin, aluminium was substituted for lead with good results.

The method finally adopted is as follows:

Method. Wet the sulphides on the filter with ammonia in an evaporating dish. Add about 15cc. polysulphide and set over a beaker of boiling water for five minutes. During the heating, the dish should be covered with a watch-glass. The contents should be stirred occasionally. Filter and treat the residue a second time with ammonia and polysulphide. Filter into the original filtrate. The residue contains all but a trace of the copper group.

Make the filtrate just acidic with dilute HCl and filter. Transfer the precipitate and paper to a dish and heat over boiling water with about 15cc. 15N ammonia for three to five minutes, adding more ammonia from time to time to replace that which boils off. This treatment dissolves the tin group sulphides. Filter, and wash the residue with warm ammonia. The residue may be added to the copper group precipitate. Acidify the filtrate with 6N HCl, being careful not to add a great excess and filter.

Transfer the paper and precipitate to a large test-tube and add 10cc. 12N HCl. Set the tube in a beaker of boiling water for ten minutes. Cool, filter, and wash the precipitate on the filter with 5cc. cold 6N HCl. Confirm arsenic in the residue.

Add 20cc. water to the filtrate. Unless this dilution causes the precipitation of orange antimony sulphide, pass in hydrogen sulphide until it starts to precipitate or to saturation if it does not appear. If antimony has precipitated, warm until it redissolves and filter. If it is absent, filter. This treatment removes all arsenic.

Boil the filtrate down to about 20cc. and transfer it to a large test-

"Proc. 38th Meeting, 1922 (1923)."

tube. Add .1-.2g. 30-mesh aluminium. Warm the solution and shake it while the metal is going into solution so as to insure contact of the metal with all parts of the solution. Continue to heat until all gas-evolution has ceased so as to avoid carrying over tin with the precipitated antimony. Let the black antimony settle to the bottom of the tube and decant the liquid through a filter into a tube containing some mercuric chloride solution. A white precipitate, which may turn gray, proves the presence of tin.

Wash the black precipitate in the tube with hot 12N HCl and with water to remove traces of tin. This may be done by decantation. Cover with 3cc. HCl, add a few drops of nitric and boil to destroy the aqua regia. Dilute to about 20cc. and pass in hydrogen sulphide. An orange precipitate proves the presence of antimony.

The writer wishes to thank his student, Mr. Merrell Fenske, for the aid he has given in working out this problem.

QUALITATIVE ANALYSIS—IRON GROUP.

Ralph W. Hufferd, DePauw University.

Careful examination of the results obtained by several classes in Qualitative Analysis has led the writer to the belief that no other group causes so much trouble or consumes so much of the students' time as does the Iron Group. Further study has brought out the fact that the most commonly missed members of this group are cobalt and zinc. The difficulty with the first of these seems to be due to faulty application of the potassium cobaltinitrite test, and with the second, to failure to extract zinc from the group precipitate and the reluctance of the average student to seek for it in the second division precipitate.

Investigation of the various tests for nickel led the writer to attempt a modification of the old Morrel-Vogel test. The results in this direction were quite satisfactory and pointed to the possibility of greatly simplifying the scheme of analysis of the whole division.

Attention was then directed toward the zinc problem. If zinc could be satisfactorily separated from the second division, the necessity for the very annoying and time-consuming second precipitation and filtration of cobalt and nickel sulphides would be avoided. This notwithstanding contrary belief on the part of certain authors, was found to be quite satisfactorily accomplished by using a large excess of sodium hydroxide in separating the two divisions. (It must be noted that this procedure may increase the quantity of silicic acid in solution, though in no case has there been evidence of nickel being present in the zinc sulphide precipitate.) There is no desire on the part of the writer to deny that small quantities of zinc may be carried over in the second group precipitate but he does hold that except in very extraordinary cases it is unnecessary to look for it as the greater part of it will show up in the proper place.

Several other slight deviations from the more commonly accepted methods will be noticed in a study of the revised method which follows. They are all in the direction of speeding up the process without lessening its accuracy.

Method of Analysis.

Dissolve the group precipitate of sulphides and hydroxides (adding the filter if difficult to separate from the precipitate) in warm 6N HCl, adding a few drops of HNO_3 if necessary (if cobalt or nickel is present). If the filter was added, remove the fibers by sucking the solution through a Hirsch funnel. Wet the pulp remaining in the funnel with water and draw the water into the filtrate. Except for particles of sulphur the pulp will be white after this treatment.

Boil the filtrate for a minute and then add 30 per cent NaOH solution until a precipitate forms and persists after shaking or, if no precipitate appears, until solution is strongly alkaline. If there is a precipitate, add a further excess of 5-10cc. NaOH. Cool and add 1-3g. Na_2O_2 a little at a time with stirring. Add about half a gram of solid Na_2CO_3 and boil for a minute or two. Dilute with two volumes of hot water and boil for three minutes. Filter hot through an ordinary filter, the writer using a suction filtration by preference. Wash the precipitate on the filter with hot water, collecting the washings with the filtrate. The filtrate is treated as directed in Noyes' "Qualitative Analysis" for the separation of the first division metals.

The paper carrying the precipitate is spread out in a dish and covered with 15cc. boiling 6N HNO_3. This treatment dissolves or loosens the precipitate from the paper so that it can be transferred to a beaker. The paper is washed with another portion of hot acid and the solution added to the other. The solution is evaporated to 10cc. and 10cc. 16N HNO_3 added. The boiling solution or suspension, as the case may be, is removed from the flame and about a gram of $KClO_3$ is added with stirring. This produces complete precipitation of the manganese as the oxide unless there is a very large quantity of it present. Twenty cc. hot water is added, the solution or suspension boiled and filtered hot through an ordinary filter. Oxalates, if present, slow up the precipitation of the manganese and sometimes necessitate a second evaporation and addition of chlorate.

The filtrate contains iron, cobalt, and nickel, and fourth group ions if phosphates, oxalates, etc. are present. When these interfering ions are absent, add quickly with stirring a volume of 15N NH_4OH 5cc. in excess of the volume of HNO_3 present. If iron is present it will appear as the brown hydroxide. Quickly heat almost to boiling and filter hot. Wash the precipitate on the filter with 2-5cc. NH_4OH, collecting it with the original filtrate. Confirm iron in the precipitate.

In a tall 150cc. beaker boil off the ammonia from the filtrate until its odor is weak but noticeable. Pour off about one-fifth of the solution and test for nickel by adding a few drops of dimethylglyoxime solution. If nickel is present, a red precipitate will form at once. It is never necessary to correct for hydrogen ion concentration in this test if the above directions are closely followed.

Evaporate the remainder of the solution to a syrupy consistency and pour it into a test tube. Cool, and add enough water to bring most of the solid into solution. The reaction at this point is acidic. Add 3cc. 10 per cent KCNS solution and then 2.5cc. amyl alcohol-ether

solution (1 vol.: 3 vol.). For convenience in the laboratory these solutions may be kept in bottles fitted with bulb tubes so marked that the correct volumes may be withdrawn and added to the solution to be tested. Shake gently. If cobalt is present the upper layer will have a distinct blue-green color. If the color is not distinct carefully add a few drops of 12N HCl to the ether layer. Presence of cobalt produces the blue color. A colorless or straw-colored layer indicates its absence. This test can be applied in most cases to the original solution if iron is absent.

When oxalates or phosphates are present, they may be removed in the usual way by precipitating the iron, cobalt, and nickel as the sulphides after removing the manganese and treating the precipitate.

Results.

The following mixtures gave good, clear-cut tests for all of the metals shown. The numbers represent milligrams of the atom named.

	Zn	Cr	Mn	Fe	Co	Ni	Al
1	—	—	9	9	1.8	9	—
2	—	—	3.6	3.6	3.6	18	—
3	—	—	1.3	13.3	.7	13.3	—
4	—	—	2	100	1	100	—
5	5	—	—	250	—	—	—
6	5	—	250	—	—	—	—
7	5	—	250	250	—	—	—
8	5	—	500	500	—	—	—
9	5	—	500	500	2	3	—
11	5	8.5	500	500	2	3	—
12	.5	—	1	—	.5	5	—
13	.5	17	18	20	10	5	—
14	2	—	500	500	1	10	—
15	10	—	100	100	2	100	100

Summary.

A simplified scheme for the analysis of the Iron Group has been worked out which takes less time and appears to give more consistent results than the methods generally used.

The troublesome reprecipitation of cobalt and nickel as the sulphides and the careful adjustment of the reaction of the solution for the dimethylglyoxime test for nickel have been eliminated.

The Morrel-Vogel test for cobalt has been improved.

A table showing the wide range of application of the scheme described is given.

The writer acknowledges indebtedness to his students, Donald Hoffman and Howard Dick for their aid with the experimental work, and to Professor J. H. Reedy of the University of Illinois and Professor J. F. G. Hicks of the University of Nevada for testing out the method with their students.

THE EFFECT OF NON-METALLIC IMPURITIES ON CEMENTITE DISTRIBUTION IN STEEL.

G. B. Wilson, Purdue University.

It is a well known fact that non-metallic inclusions in iron and steel exert injurious and very undesirable effects upon the metal. Since it has been impossible entirely to eliminate their presence they have been the subject of much investigation and discussion.

Their weakening effect upon the steel is much more pronounced than can be explained by assuming that they are essentially the same in their effect as would be produced by cavities of the same size. Inclusions which may occupy a very small proportion of the cross sectional area of a given piece of steel very often prove fatal, whereas the total effective area of the metal lying between the inclusions would seem to be sufficient to withstand the strain. Their importance to the manufacturer and to the user of steel then is vastly greater than their size might at first indicate.

When pure hyper-eutectoid steel (steel containing more than 0.87 per cent carbon and generally called high carbon steel) is heated above its critical range it is composed of austenite. The upper limit of this range varies from 725° to 1125°C as the carbon content varies from 0.87 to 1.7 per cent. Austenite is essentially solid iron with carbon in the form of iron carbide (Fe_3C) dissolved in it. Iron carbide as a constituent of steel is called cementite. If the steel is slowly cooled nothing happens except that the austenite grains increase in size until the first recalescent point Ar^{cm} is reached. At this point the unsaturated austenite of higher temperature becomes saturated with cementite and the latter is thrown out of solution. As the temperature continues to fall the austenite continues rejecting cementite until the second recalescent point Ar_1 is reached when austenite of eutectic composition remains and is changed bodily into pearlite. Pearlite then is the mixture of eutectic composition stable below the Ar_1 point and consists of a conglomerate of carbonless iron (ferrite) and iron carbide (cementite).

Figures 1*a* is a photomicrograph of an annealed hyper-eutectoid steel which has been highly polished and etched with a solution of nitric acid in alcohol in order to show the grain structure. Each irregular cell-like area is a grain of this conglomerate, pearlite. The light network and areas between the pearlite grains represent the excess cementite above that required to form the eutectic and which was rejected to the grain boundaries as the steel cooled.

In the case of hypo-eutectoid steel (steel containing less than 0.87 per cent carbon) the iron or ferrite instead of cementite is in excess of that required for eutectic composition, consequently ferrite is thrown from solution as it cools through the critical range and the cooled steel consists of pearlite and ferrite. Figure 1*b*, shows a hypo-eutectoid steel in which the network and light areas are ferrite. The dark constituent is again pearlite.

"Proc. 38th Meeting, 1922 (1923)."

In ordinary annealed hyper-eutectoid steel inclusions are generally found within the cementite areas. In the case of hypo-eutectoid steel they usually occur in the ferrite grains and ferrite network surrounding

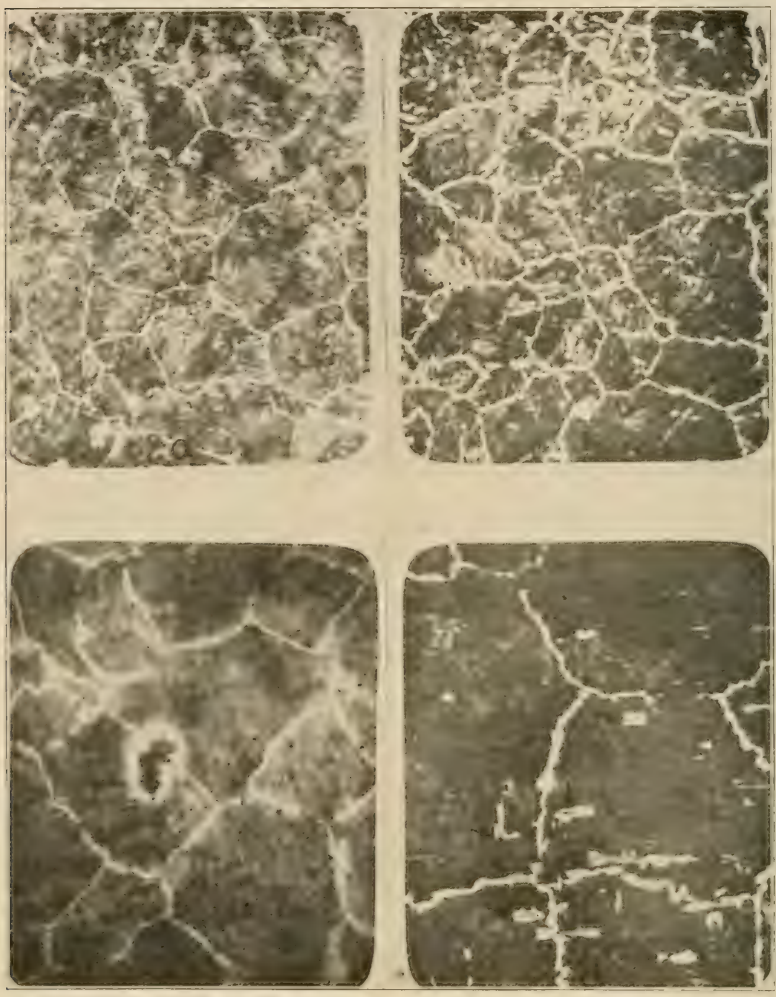


Fig. 1. a, Pearlite grains (dark) and cementite (light) in annealed hyper-eutectoid steel; b, pearlite grains (dark) and ferrite (light) in annealed hypo-eutectoid steel; c, inclusion surrounded by cementite in hyper-eutectoid steel; d, inclusions surrounded by ferrite in hypo-eutectoid steel, a and b etched with nitric acd, c and d with hydrochloric acid. x 80.

pearlite grains but rarely in the pearlite grains themselves. Figure 1*c* is a rather striking example of an inclusion surrounded by cementite in hyper-eutectoid steel. Figure 1*d*, shows a hypo-eutectoid steel. It

will be noted that practically all the inclusions occur in the light ferrite areas.

Segregation about inclusions cannot be destroyed by ordinary heat treatment, such as would break up ordinary grain formations. Besides being areas of little or no strength they then act as obstacles to the proper thermal treatment of the metal.

Whether inclusions are the cause of the segregation of cementite in hyper-eutectoid and ferrite in hypo-eutectoid steel or whether their co-existence is the result of some common and deeper seated cause has been the subject of considerable discussion.

Stead[1] pointed out that in the case of hypo-eutectoid steel the inclusions surrounded by ferrite generally occur in areas rich in phosphorus and he held that the phosphorus is the real cause of the ferrite segregation and that the presence of the inclusions is merely incidental. He believed that the inclusions themselves are not the cause of this segregation.

Howe[2] expressed the opinion that the presence of the inclusions within the ferrite or cementite areas is due to the tendency of the steel in the process of cooling to reject both inclusions and the ferrite or cementite to the grain boundaries.

Brearly[3] and Ziegler[4] suggested that the inclusions might act as nuclei for ferrite or cementite crystallization in a manner similar to a string suspended in a sugar solution.

Work in this laboratory[5] has led to the conclusion that the cause of ferrite and cementite segregation about inclusions is due to the fact that the inclusion itself or some reaction product of it with the surrounding steel is soluble to a slight extent in the metal at high temperatures and that this introduction of a third component into the solid solution system of iron and iron carbide so alters solubility relations that supersaturation is reached at a higher temperature in the metal immediately surrounding the inclusion than in the rest of the steel. If there is a zone, however narrow, lying about the inclusion and containing even a trace of any dissolved material from the inclusion, this foreign material should alter the solubility of the excess ferrite or cementite in the austenite next the inclusion and thus cause a local condition of supersaturation first in this region. The excess constituent then would separate here first. After separation had started it would continue about these spots as nuclei as the steel cooled farther and consequently the inclusions would be imbedded in the cementite or ferrite.

Under the direction of Dr. E. G. Mahin the writer undertook to study the effect produced upon cementite distribution in hyper-eutectoid steel when artificial inclusions of known composition were placed in the metal.

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[1] J. Iron Steel Inst., *97*, 287 (1918).

[2] "The Metallography of Steel and Cast Iron", 280.

[3] Proc. Sheffield Soc. Eng. Metallurgists, 1919.

[4] Rev. metall., *8*, 655 (1911).

[5] J. Ind. Eng. Chem., *11*, 739 (1919).
Ibid., *12*, 1090 (1920).

Small blocks were cut from a bar of ordinary commercial high carbon steel of the following composition; carbon, 1.2; manganese, 0.30; phosphorus, 0.02; sulphur, 0.03; silicon, 0.20 per cent.

The method of preparing these specimens was the same as previously used in the study of inclusions in low carbon steel. This consisted in drilling holes through the blocks. At the same time rods of several alloys and special steels were turned on the lathe to a diameter slightly larger than the holes. After cleaning both rods and holes with an alcohol ether mixture the rods were driven into the holes and hammered until the contact between the two pieces was very intimate.

The alloy or special steel insert now occupied the same relation to the main body of high carbon steel as a natural inclusion might occupy in the same position.

The specimens so prepared were heated well above the transformation range of the steel for varying periods of time after which they were allowed to cool slowly in the furnace. After this treatment a section was cut from each specimen perpendicular to the axis of the insert so that the zone about the contact between it and the main body of the piece might be subjected to examination for evidence of cementite segregation.

In order to study in a more definite manner the effect upon carbon distribution produced by the localization of a few of the more common elements generally found in ordinary commercial steels inserts were made of several specially prepared steels.

Number 1 was a plain carbon steel containing about 0.5 per cent carbon. The other seven were of identical composition except that to each had been added some element in excessive amount. For example to number 2 had been added silicon and to number 3 phosphorus, etc. The amount of the added element found in each of the entire set follows:

No. 1 Plain 0.5 per cent carbon steel.
No. 2 Plain 0.5 per cent carbon steel plus 4.0% silicon.
No. 3 Plain 0.5 per cent carbon steel plus 1.06% phosphorus.
No. 4 Plain 0.5 per cent carbon steel plus 1.46% manganese.
No. 5 Plain 0.5 per cent carbon steel plus 1.34% copper.
No. 6 Plain 0.5 per cent carbon steel plus 0.84% chromium.
No. 7 Plain 0.5 per cent carbon steel plus ..... titanium.
No. 8 Plain 0.5 per cent carbon steel plus 1.36% sulphur.

Several non-ferrous alloys also were used for inserts. Among them were alumel, an alloy of aluminium and nickel; copel, an alloy of copper and nickel; and chromel, an alloy of chromium and nickel.

The specimen with the insert of plain carbon steel and which contained no excessive amount of any element showed no tendency to cause the separation of cementite. It was found however that the diffusion from some of the other inserts into the adjacent steel had a tendency to cause cementite to segregate in this region while with other inserts containing other elements this tendency did not manifest itself under the conditions of the experiment. A few photomicrographs will show the nature of this effect.

Figure 2*b*, shows the appearance of the specimen containing the high silicon insert after it had been heated at 950°C. for three hours. There is a narrow but well defined band of cementite about the insert.

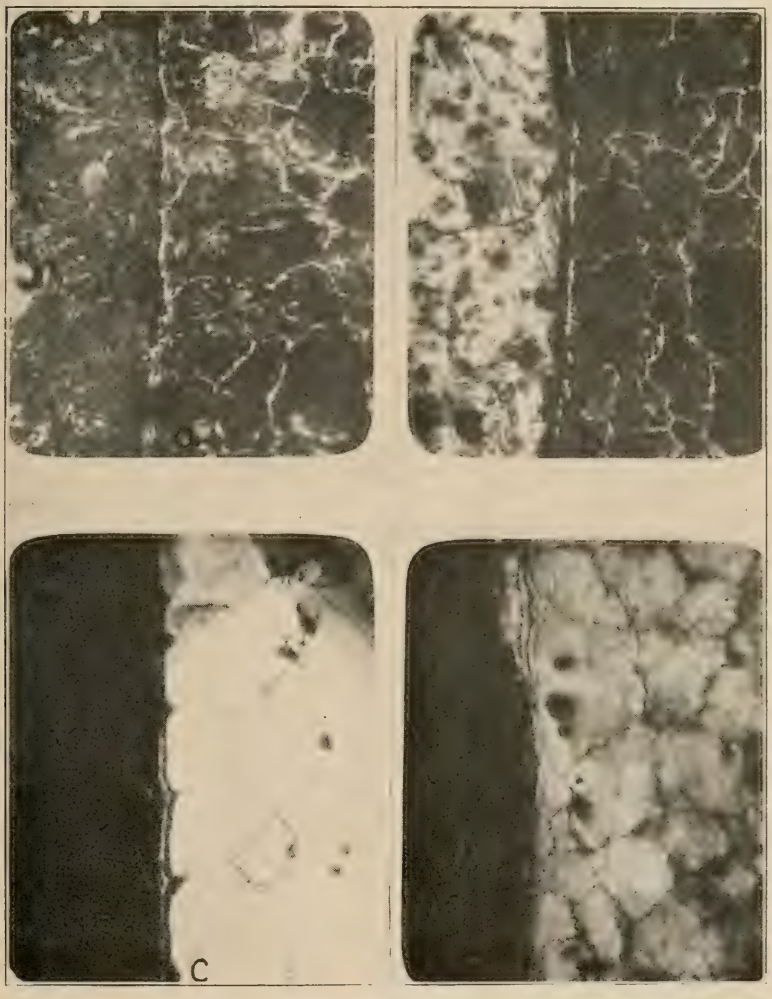

Fig. 2. a, Cementite segregated about high phosphorus insert in hyper-eutectoid steel; b, cementite segregated about high silicon insert in hyper-eutectoid steel; c, cementite segregated about alumel insert in hyper-eutectoid steel; d, cementite segregated about copel insert in hyper-eutectoid steel. a and b etched with nitric acid, c and d with sodium picrate. x 80.

The width of this zone corresponds to the depth to which the material from the insert had penetrated into the surrounding steel. This diffused material was probable iron silicide.

Figure 2*b*, shows the high-phosphorus insert. Here again the extent to which the phosphorus had penetrated into the steel is marked by a zone of cementite. This was heated at 900 for two hours.

The other steel inserts containing manganese, copper, chromium, titanium, and sulphur showed this tendency to cause cementite segregation to only a very limited extent or not at all.

Figure 2, *c* and *d*, respectively, show the specimens containing alumel and copel inserts. Cementite has collected about the insert in both cases. These specimens were etched with sodium picrate which causes cementite to appear dark.

From the results of these few experiments it would seem that inclusions in hyper-eutectoid steel must have a certain slight solubility in the austenite at high temperatures, and that the concentration of the dissolved matter is therefore greatest in the immediate vicinity of the inclusion. Such a condition of localized dissolved impurities probably has the effect of starting cementite crystallization first about the inclusion, thus breaking down the state of cementite supersaturation that always occurs in hyper-eutectoid steel cooling through the critical range. And since each inclusion is a center of contamination and furnishes a continuous supply of impurity to the surrounding steel no amount of heat treatment can eliminate its effect.

A STUDY OF, AND A MODIFIED METHOD FOR, VOGEL'S REACTION FOR COBALT.

F. J. Allen and A. R. Middleton, Purdue University.

Among the more sensitive tests for cobaltous ion and one particularly suitable for detection of traces of cobalt in nickel salts is the reaction with thiocyanate, usually called Vogel's reaction. When an aqueous solution of a nickel salt, to which excess of ammonium thiocyanate has been added, is shaken with a mixture of equal parts of amyl alcohol and ethyl ether, even minute amounts of cobalt form a blue compound which dissolves in the ether-alcohol layer. Nickel remains entirely in the aqueous layer. Iron, if present in traces only, causes the color to appear purple but the interference of this element can be overcome as shown below. Although easily performed and requiring only reagents ordinarily available, especially in the modified procedure to be described, this test is mentioned in few textbooks of chemical analysis and seems to be not very widely known.

HISTORICAL. In 1877 Morrell[1] noted that cobalt salts, when added to a neutral or acid solution of ammonium thiocyanate in alcohol, give a blue color becoming pink on dilution. He proposed the use of this reaction for determining alcohol. Two years later Zimmerman[2] proposed a separation of iron from cobalt and nickel by excess of ammonium thiocyanate and precipitation of the iron as hydroxide by sodium carbonate solution added to the point of discharge of the red color of ferric thiocyanate. About the same time Wolff[3] studied the absorption spectra of cobalt thiocyanate solutions. Slightly later Vogel[4] proposed the reaction as a test for cobalt, removing iron by Zimmerman's method and dissolving the blue compound into a mixture of equal parts of amyl alcohol and ether. He stated that by the characteristic absorption spectrum of the blue ether-alcohol layer 1 part of $CoCl_2$ in 400 parts of $FeCl_3$ or in 200 parts of $NiCl_2$ could be detected easily.

Vogel's work remained practically unnoticed until 1900 when Treadwell[5] called attention to it and showed that the reaction is capable of detecting 0.02 mg. of cobalt in presence of large amounts of nickel. He also isolated the blue compound dissolved in the ether-alcohol layer and found its composition to be that of a double salt, $Co(SCN)_2 .2NH_4SCN$. At about the same time Rosenheim and Cohn[6] by migration experiments showed that the blue compound contains a complex anion since cobalt migrated to the anode. They prepared nickel double thiocyanates in crystalline form having the general formula, $Ni(SCN)_2 .4RSCN$, and found that in their solutions complex anions were not present, as nickel migrated only to the cathode. In Treadwell's Analytical Chemistry this reaction is included among the tests for cobalt. He prescribes neutral

[1] Z. analyt. Chem., 16, 251.
[2] Ber., 12, 2254.
[3] Ber., 12, 2314.
[4] Z. analyt. Chem., 18, 38.
[5] Z. anorg. Chem., 26, 108.
[6] Z. anorg. Chem., 27, 280.

"Proc. 38th Meeting, 1922 (1923)."

solution and suppresses iron, when present, by ammonium acetate and tartaric acid.

In this laboratory it was observed some years ago that when ethyl alcohol is substituted for amyl alcohol and potassium thiocyanate for the ammonium salt, a blue color is developed in the aqueous layer which does not pass into the ether layer until mineral acid is added. It was found that under these conditions cobalt could be readily detected in nickel salts in which the procedure recommended by Treadwell failed to show the presence of this element. Of many salts examined only one, a Kahlbaum's "kobalt-frei" $NiSO_4$, failed to show the presence of cobalt. Since nickel salts usually contain iron, a purple instead of blue color appeared in the ether layer. It was found that shaking with a few small crystals of sodium thiosulfate quickly reduced the iron and a pure blue color remained.

It appeared desirable to study this modification of the Vogel reaction in greater detail in order to fix more certainly the conditions of concentration under which it is most delicate and reliable and to compare the delicacy of the test in neutral and in acid solution. It seemed probable that in acid solution the blue ether-soluble compound might be the acid of a complex anion, e.g., $H_2Co(SCN)_4$, and that such an acid might be isolated from the ether solution. Two such complex acids have been obtained in crystalline form, $H_2Hg(SCN)_4$[1] and $HAu(SCN)_4.2H_2O$.[2]

EXPERIMENTAL. A solution of cobalt nitrate was prepared by dissolving electrolytic nickel-free cobalt in nitric acid, removing excess of acid by evaporation and diluting with water. This solution was standardized (1) by igniting the nitrate and weighing as Co_3O_4; (2) by conversion to anhydrous sulfate. The cobalt content per cc. as found by the first method was 8.401 mg. and by the second 8.391 mg.; average, 8.396 mg. By accurate dilution solutions were prepared containing respectively, 1.0, 0.1, 0.01 and 0.001 mg. of cobalt per cc. Standard solutions of ammonium, potassium and sodium thiocyanates and of hydrochloric and sulfuric acids were also prepared.

A. *Treadwell-Vogel Test (Neutral solution).* The effect of varying the concentrations of the various components of the test solution was studied and the conditions determined under which the test is most delicate. The optimum conditions were found to be high concentration of thiocyanate, small total volume and small volume of the ether-alcohol layer. For example, 5cc. of 4 normal Na, K, or NH_4 thiocyanate, 2.5 cc. of saturated ammonium acetate and 0.5 cc. of cobalt nitrate (0.001 mg. per cc. Co) when shaken with 1 cc. of 1:1 mixture of amyl alcohol and ethyl ether gave a faint but distinct blue color in the ether-alcohol layer when this was observed against a white background. Under these conditions 0.0005 mg. of Co in a total aqueous volume of 8 cc. is clearly detectable. Treadwell's statement that 0.02 mg. of cobalt is detectable is conservative. Not much difference was observed in the effectiveness of the three alkali thiocyanates but it was noticed that

[1] Rosenheim and Cohn, loc. cit.

[2] Bjerrum and Kirschner, Die Rhodanide des Goldes—Mem. acad. roy. sci. lettres Danemark, 8me serie, V, No. 1, p. 20.

traces of iron interfered less when the sodium salt was used. This is in accord with the observation of Rosenheim and Cohn[1] that of the three alkali-ferric thiocyanates, $R_3Fe(SCN)_6$, prepared by them the sodium salt is most stable and least decomposed by aqueous ether into $Fe(SCN)_3$, which is soluble in ether and NaSCN insoluble in ether.

B. *The Vogel Test in acid solution.* The effect of varying a single component of the test solution while keeping the others constant is shown in the tables following.

TABLE 1. Effect of acid concentration.

0.01 mg. Co, 1 cc. 4 N NH_4SCN, 0.3 cc. C_2H_5OH, 1.2 cc. $(C_2H_5)_2O$; total volume 5 cc.

H_2SO_4 normality in 5 cc.	Color in alcohol-ether layer	HCl normality in 5 cc.	Color in alcohol-ether layer
0.0	none	0.0	none
0.2	faint blue	0.2	faint blue
0.4	faint blue	0.4	faint blue
0.6	deeper blue	0.6	deeper blue
0.8	maximum blue	0.8	maximum blue
1.0	maximum blue	1.0	maximum blue
1.5	maximum blue	1.5	maximum blue
3.0	weaker blue	3.0	weaker blue
6.0	pale blue	5.0	none
9.0	greenish blue		

TABLE 2. Effect of thiocyanate concentration.

0.01 mg. Co, 0.8 cc. 5 N HCl, 0.3 cc. C_2H_5OH, 1.2 cc. $(C_2H_5)_2O$; total vol., 5cc.

Normality of thiocyanate in 5 cc.	Color in alcohol-ether layer
0.0	none
0.08	none
0.4	faint blue
0.8	maximum blue
1.36	maximum blue

[1] Loc. cit.

TABLE 3. Effect of ethyl alcohol.

0.01 mg. Co, 1cc. 4 N NH_4SCN, 0.8 cc. 5N HCl, 1 cc. ether; total vol. 5 cc.

Per cent alcohol in 5 cc.	Color in ether or ether-alcohol layer.
0.0	faint blue
1.0	slightly bluer
2.0	slightly bluer
4.0	maximum blue
6.0	maximum blue
8.0	maximum blue
16.0	maximum blue
20.0	maximum blue

TABLE 4. Limit of sensitiveness.

1 cc. 4 N NH_4SCN, 1 cc. 5 N HCl, 0.3 cc. alcohol, 1.2 cc. ether; total vol. 5 cc.

mg. Co	Color, ether-alcohol layer
0.0	none
.001	very faint blue
.002	pale blue
.003	pale blue
.004	clear, sky blue

Repetition using KSCN and NaSCN in place of NH_4SCN gave the same tints for each concn. of Co.

TABLE 5. Comparison of sodium, potassium and ammonium thiocyanates in neutral solution.

1 cc. 4 N alk. thiocyanate, 2 cc. ether, 0.5 cc. C_2H_5OH; total vol. 5 cc. (The sodium and potassium salts gave identical results).

mg. Co	Color, KSCN or NaSCN		Color, NH_4SCN	
	aqueous layer	ether layer	aqueous layer	ether layer
0.1	sky blue	none	sky blue	very faint blue
1.0	deep blue	very faint blue	deep blue	deep blue
1.5	deep blue	pale blue	deep blue	deep blue
55.0	indigo blue	deep sky blue	indigo blue	slightly paler than aqueous layer

TABLE 6. Comparison of 1:1 amyl alcohol-ether with 1:4 ethyl alcohol-ether in acid solution.

1 cc. 4 N NH_4SCN, 1 cc. 5 N HCl; total vol. 5 cc.

mg. Co	Color, amyl alcohol-ether	Color, ethyl alcohol-ether
0.001	none	faint blue
.002	faint blue	distinct blue

TABLE 7. Ethyl alcohol in neutral solution as a reagent for cobalt.

1 cc. 4 N NaSCN; total vol. 5 cc.

Per cent C_2H_5OH in total volume	Color 0.01 mg. Co	Color 0.1 mg. Co
20	none	none
30	barely perceptible blue	pale blue
40	pale blue	bright blue
50	pale blue	bright blue
60	pale blue	bright blue

Discussion of Results. Table 1 shows that the maximum color is developed when the solution is at least 0.8 normal in acid and that increase of acid concentration up to 1.5 normal is without effect. Weakening or disappearance of the blue color at acid concentrations above 3 normal is to be expected if the blue compound is a complex anion. By forming little ionized HSCN high concentration of hydrogen ion should tend to decompose the blue complex and this decomposition should be proportional to the concentration of mineral acid.

Table 2 shows that the thiocyanate concentration should be at least 1 normal and that concentrations above this do not increase the sensitiveness of the test.

Table 3 shows that when the aqueous layer contains only 4 per cent ethyl alcohol the solubility of the blue compound in ether reaches a maximum and that increase of alcohol concentration up to the point where an ether layer no longer separates does not cause any increase of sensitiveness.

Table 4 shows that in acid solution the three alkali thiocyanates used are equally effective as would be expected. Under the optimum conditions of concentration 0.001 mg. of cobalt is detectable in 5 cc. of solution. In neutral solution, however, as appears from table 5, the ammonium complex salt is distinctly more soluble in ether than the sodium or potassium salts. That addition of a little mineral acid to the blue aqueous layer drives all the blue compound into the ether layer is evidence that the ether-soluble compound is a complex acid and not a salt, such as $Co(SCN)_2$ or $Na_2Co(SCN)_4$. Additional evidence upon this point will be presented in another paper.

Table 6, which compares the effectiveness of amyl alcohol-ether, 1:1, used with neutral aqueous solution of ammonium thiocyanate, with 1:4 ethyl alcohol-ether, used with aqueous solution of any alkali thiocyanate 1 normal in mineral acid, shows that the greater solubility in ether of the free complex acid as compared with that of the ammonium salt makes the test slightly more delicate when performed in acid solution. In presence of large quantities of nickel salts this advantage becomes still more marked. In acid solution the interference of ferric iron is considerably greater but this is quickly and easily reduced by shaking with a few crystals of sodium thiosulfate which does not affect at all the reaction with cobalt.

Table 7 shows that in water-alcohol mixtures fairly high in alcohol quite small amounts of cobalt are able to give a distinct color. As the solutions here were neutral, the sodium complex salt must be assumed present. Under these conditions, however, the green color of nickel salts would interfere with the detection of small amounts of cobalt.

Summary.

1. Treadwell's method of carrying out the Vogel test for cobalt in neutral solution using equal parts of ether and amyl alcohol was studied by varying the components of the reaction mixture one by one while keeping the others constant. The optimum conditions were found to be high concentration of thiocyanate, small aqueous volume and small

volume of the ether-alcohol mixture. As little as 0.001 mg. of cobalt in 8 cc. can be detected under these conditions. If only traces of iron are present, it causes less interference when NaSCN is used than when the ammonium salt prescribed by Treadwell is used. The interference of larger quantities of iron is not very satisfactorily overcome by ammonium acetate and tartaric acid.

2. In acid solution and using a small amount of ethyl instead of amyl alcohol the test is at least equally delicate. The optimum conditions were found to be concentrations of thiocyanate and of H_2SO_4 or HCl about 1 normal each and addition of ethyl alcohol equal to about 5 per cent by volume of the aqueous layer and no more ether than required to form a separate layer. In acid solution ferric iron is readily and quickly reduced by shaking with a few crystals of sodium thiosulfate. Even moderately large amounts of iron cause no interference with the test for cobalt. The easy removal of interference by iron, the more general availability of ethyl as compared with amyl alcohol, and that any one of the alkali thiocyanates may be used are features which recommend the test in acid solution as a preferable modification.

THIOCYANATOCOBALTOUS ACID AND ITS ALKALI SALTS.

F. J. Allen and A. R. Middleton, Purdue University.

When an aqueous solution of $K_2Co(SCN)_4$, to which sufficient KSCN has been added to make the solution 0.8-1.0 normal in thiocyanate, is shaken with sufficient 1:4 ethyl alcohol-ether to form a separate layer, only traces of a blue compound pass into the ether layer. If the solution be now acidified with mineral acid, practically all the blue compound passes into the ether layer. As the blue color has been shown by Rosenheim and Cohn[1] to be due to a bivalent complex negative ion, $Co(SCN)_4''$ it appears probable that in the acid solution the free acid, $H_2Co(SCN)_4$, may be formed which is readily soluble in ether while its potassium salt is nearly insoluble. Two similar acids, $H_2Hg(SCN)_4$[2] and $HAu(SCN)_4 .2H_2O$,[3] have been isolated in solid, crystalline form. Preliminary attempts to isolate the acid in solid form, by evaporation of the ether solution in an evacuated desiccator, showed that large amounts of HSCN were evolved as the solution concentrated. A mixture was deposited consisting of long slender needles of deep blue color which showed a strong acid reaction when moistened with water and short needles of a bluish green color. No method of separating the two sufficiently for analysis has been found up to this time. In order to obtain some information as to the nature of the ether-soluble blue compound, experiments were made to determine the partition of acid, thiocyanate and cobalt between the aqueous and ether layers at 25° C.

Preliminary determinations were made of the partition of sulfuric acid and of thiocyanic acid. These are recorded in the following tables.

TABLE 1. Partition of H_2SO_4 between water and 1:4 alcohol (EtOH)-ether (Et_2O).

	Normality of acid.	
Expt. No.	Aq. layer	Et_2O Layer
1	0.8005	0.0037
2	1.7112	0.0074

The solubility of H_2SO_4 in aqueous ether is very small and in comparison with the large solubility of HSCN shown in the next table is negligible at total concentrations not above 1.5 normal.

[1] Z. anorg. Chem., 27, 280 (1900).

[2] Rosenheim and Cohn, loc. cit.

[3] Bjerrum and Kirschner, Die Rhodanide des Goldes, Mem. acad. roy. sci. lettres, Danemark, 8me serie, V, No. 1, p. 20.

TABLE 2—Partition of HSCN between water and 1:4 EtOH-Et_2O.

In each experiment 10 cc. 4 normal NaSCN (SCN=0.04 equiv.)

Expt. No.	5-N. H_2SO_4 cc.	Volume cc.		Acid normality		SCN normality		Ratios		
		aq.	Et_2O	aq.	Et_2O	aq. (by dif.)	Et_2O	Et_2O H^+ to aq. H^+	Et_2O SCN to aq. SCN	Et_2O SCN to Et_2O H^+
1	0	*	*	0.0	0.0	.....	0.0087	.....	.....	.....
2	1	32	26	.0440	.1651	1.108	.1744	3.75	0.157	1.056
3	3	26.5	24.5	.1908	.4801	1.042	.5060	2.52	.486	1.054
4	5	24	24	.3890	.7230	0.9078	.7590	1.86	.836	1.050
5	7	22	24.5	.6680	.9360	.7736	.9380	1.40	1.212	1.002
6	9	19	25	1.082	1.098	.5850	1.155	1.15	1.974	1.052
7	20	32	30	2.280	1.122	.1625	1.160	0.49	7.139	1.034

*Not recorded.

In the above table, experiment 1 shows that NaSCN has a very small but appreciable solubility in aqueous ether. Unfortunately, the volumes of the aqueous and the ether layers in this experiment were not recorded so that the ratios in the last column could not be corrected for dissolved salt. The slight excess of thiocyanate is undoubtedly due to this cause. The close approximation of the last ratio to unity shows that the ether-soluble substance is practically all HSCN. The data clearly show that this acid is far more soluble in ether than in water. A small excess of mineral acid is sufficient to force nearly all the thiocyanate into the ether layer as HSCN.

The data recorded in table 3 were obtained as follows. In a tall glass-stoppered cylinder were placed 25 cc. of an aqueous solution of $K_2Co(SCN)_4$ in which the cobalt content was 71.0 mg., 10 cc. of 4 normal KSCN, the recorded volumes of 5 normal H_2SO_4, (in Expt. 9, 5 cc. of 33 normal acid) and sufficient 1:4 ethyl alcohol-ether to give approximately equal layers. The cylinder was placed in a bath at 25° C. and frequently shaken until equilibrium was reached. In separate portions of the ether layer acidity was determined by titration with NaOH and phenolphthalein, SCN by titration with AgNO and ferric alum, and cobalt by evaporation with H_2SO_4 and weighing as $CoSO_4$. Acid in the aqueous layer was also determined. In experiment 9, only 20 cc. of the $K_2Co(SCN)_4$ solution were taken.

The ratio $\frac{1}{2}Co:SCN$, together with the data of columns 8 and 12, indicates a small solubility of $Co(SCN)_2$ in aqueous ether containing a little alcohol. This was confirmed using a sample of the purple $Co(SCN)_2 3H_2O$ which, although not very pure as shown by analysis, showed all the reactions of this salt. When placed in ether the latter assumed only a faint tinge of blue. The solubility calculated from the data of experiment 1 is 0.347 mg. per cc. for the anhydrous salt.

The ratios, $H^+:\frac{1}{2}Co:SCN$ and $(SCN-\frac{1}{2}Co):H^+$, confirm the conclusion from table 2 that HSCN is largely soluble in ether and that its concentration in the ether layer increases rapidly as the mineral acid in the aqueous layer is increased.

The data throw no light on the formula of the ether-soluble, blue cobalt compound. In not too acid solutions about 20 mols. of HSCN for each mol. of $Co(SCN)_2$ are present. This may indicate either a

TABLE 3. Partition of Co and HSCN between water and 1:4 alcohol-ether. In each experiment 10 cc. 4 N KSCN. In experiments 1-8, 71.0 mg. Co=0.020404 equiv.; total SCN=0.080808 equiv. In experiment 9, 0.016323 equiv. Co and 0.072646 equiv. SCN.

Expt. No.	5—N H_2SO_4 cc.	Volume cc.		Acid normality		SCN normality		$CoSO_4$ mg. per cc.		Cobalt normality		Ratio in Ether layer			Ratio		Fraction of total Co in Et_2O layer
		aq.	Et_2O	aq.	Et_2O	aq. by dif.	Et_2O	aq. by dif.	Et_2O	aq. by dif.	Et_2O	H^+ to	½ Co	to SCN	(SCN—½ Co)	to H^+	
1	0	51	42	0.0	0.0	1.581	0.004	3.402	0.312	0.0439	0.004	0.0	1	1	—	—	—
2	1	50	44	0.0330	0.0945	1.521	0.109	3.020	0.808	0.0389	0.0104	9.086	1	10.48	1	1.0435	0.211
3	3	49	48	0.0945	0.2496	1.367	0.288	1.986	1.860	0.0256	0.0240	10.04	1	12.00	1	1.058	0.4837
4	5	49	48	0.2090	0.3590	1.265	0.392	1.308	2.552	0.0168	0.0329	10.91	1	11.91	1	1.0003	0.661
5	7	50	48	0.363	0.4476	1.135	0.502	0.764	3.092	0.0099	0.0398	11.24	1	12.60	1	1.0310	0.802
6	9	51	46	0.495	0.5280	1.030	0.593	0.571	3.424	0.0074	0.0442	10.94	1	13.39	1	1.0395	0.857
7	11	53	45	0.646	0.580	0.984	0.637	0.641	3.392	0.0083	0.0438	13.24	1	14.54	1	1.1023	0.841
8	15	55	44	0.910	0.653	0.865	0.755	0.705	3.360	0.0091	0.0438	14.90	1	17.21	1	1.089	0.827
9	5cc. 33 N	35	57	3.630	0.770	0.797	0.785	1.574	1.652	0.0203	0.0213	36.15	1	36.80	1	0.992	0.512

definite compound, $H_{2x}Co.(SCN)_{4x}$, a mixture of several such acids, or an acid of definite formula along with a large excess of HSCN. That upon evaporation the ether solution deposits deep blue crystals having a strong acid reaction makes it probable that a definite acid, $H_{2x}Co.(SCN)_{4x}$, is present and that it is capable of existence in solid crystalline form. The problem of obtaining this compound sufficiently pure for analysis is being further investigated.

The conclusion drawn from table 1 of the preceding paper on Vogel's reaction, that the fraction of cobalt which passes into the ether layer reaches a maximum at moderate concentrations of mineral acid and then decreases as the acid is increased, is clearly verified by the data of table 3 above, as shown in the last column.

Alkali salts of Thiocyanatocobaltous Acid. Deep blue double thiocyanates of cobalt and alkali metals have been prepared in crystalline form by Treadwell[1] and by Rosenheim and Cohn.[2] These investigators agree in assigning to these salts the empirical formula, $Co(SCN)_2.2RSCN$, in which R may be NH_4, K or Na, but they differ as to their properties and hydration. By transference experiments Rosenheim and Cohn proved that the blue color was due to a complex anion, $Co(SCN)_4''$. Treadwell, working with organic solvents, obtained the potassium and ammonium salts in anhydrous condition and found them to be quickly decomposed by water and even by moist air. Rosenheim and Cohn prepared 12-14% solutions of HSCN by action of H_2S on concentrated solutions of $Hg(SCN)_2$ and by action of this acid on $CoCO_3$ prepared cobalt thiocyanate in violet rhombic crystals of composition $Co(SCN)_2.3H_2O$. By addition of the calculated amounts of the various alkali thiocyanates to aqueous solutions of this salt they obtained in well defined crystalline form the potassium and ammonium salts, each with 4 molecules of water, and the Na and Ba salts each with 8 molecules of water. They found all these salts to be soluble in methyl, ethyl and amyl alcohol and in acetone and that they could be recrystallized from concentrated aqueous solution without decomposition. They also prepared the anhydrous salts by Treadwell's methods and from aqueous solutions of these obtained the hydrated salts without decomposition. It seemed worth while to investigate these discrepant statements.

A simpler method of preparing the potassium salt and also $Co(SCN)_2.3H_2O$ was worked out. The work described below verifies the statements of Rosenheim and Cohn but it was found that the tri-hydrate is the form of the potassium and ammonium salts which is stable in air at the temperature of the laboratory, although, as stated by Rosenheim and Cohn, the tetra-hydrate separates from aqueous solution. The loss of one molecule of water is not accompanied by any change in the appearance of the crystals. The sodium complex salt was not prepared.

Experimental.

To concentrated aqueous solution of $CoSO_4$ was added the amount of KSCN calculated to form the double salt and then ethyl alcohol in

[1] Z. anorg. Chem., 26, 108 (1900).

[2] Loc. cit.

large excess. Most of the K_2SO_4 precipitates and can be filtered off. The deep-blue alcoholic solution was evaporated on a water bath nearly to dryness and alcohol added. More K_2SO_4 could now be removed and three or four repetitions of this process proved sufficient for the complete removal of sulfate. The sulfate-free alcoholic solution was evaporated with occasional additions of a little water until the alcohol was removed and the concentrated aqueous solution allowed to crystallize at room temperature. Crystals of the potassium salt several centimeters long were thus obtained. Analysis of the crystals, removed from the mother liquor and dried by pressing between filter paper, gave: SCN—52.65%; Co=13.53%. $K_2Co(SCN)_4.4H_2O$ requires SCN=52.61; Co=13.35.

After exposure to air: 24 hours, SCN=54.99%; Co=13.69%; 96 hours, SCN=55.09%, Co=14.29%; 144 hours, SCN 55.15%, Co 14.04%. $K_2Co(SCN)_4.3H_2O$ requires SCN—54.85%, Co—13.92%. Evidently the trihydrate, and not the tetrahydrate, is the form stable in air at room temperature.

The ammonium complex salt was prepared in anhydrous form by precipitation from its acetone solution by chloroform and dried in air. Found, SCN=69.17%; $(NH_4)_2Co(SCN)_4$ requires SCN=70.97%. The salt was dissolved in water and the solution, when evaporated at low temperature, yielded fine blue needles often several centimeters long. This material, when removed from the mother liquor and dried by pressing between filter paper, gave SCN—60.75%; after exposure to air 48 hours, 60.44%; after 72 hours, 61.03%; after 96 hours, 61.22%. The tetrahydrate requires SCN=58.16%; the trihydrate requires SCN 60.91%. The trihydrate appears to be the form of the ammonium salt also which is stable in air at room temperature.

By the same method of removal of alkali sulfate by alcohol it was found possible to obtain the purple $Co(SCN)_2.3H_2O$ by adding to concentrated aqueous solutions of $CoSO_4$ the calculated amount of NaSCN. The product was well crystallized and contained only a spectroscopic trace of sodium. In appearance and reactions it corresponded exactly with the description of Rosenheim and Cohn but analysis gave Co=22.17%, SCN=54.19%. $Co(SCN)_2.3H_2O$ requires Co=25.77%, SCN=50.66%. This salt is unstable in air and passes into a yellow-brown substance, readily soluble in alcohol to a deep-blue solution and in appearance corresponding to the hemihydrate, $Co(SCN)_2.{}^1/_2H_2O$, described by Rosenheim and Cohn.

Summary.

1. The partition of cobalt between water and aqueous-alcoholic-ether in presence of thiocyanic acid was studied. The ether layer was found to contain equivalent proportions of cobalt and thiocyanate, in addition to large amounts of thiocyanic acid, but to dissolve practically no cobalt thiocyanate or alkali thiocyanate.

2. The data obtained in this study do not permit definite conclusion as to the formula, or formulas, of the extremely ether-soluble blue cobalt compounds, although the evidence makes it highly probable that one or more complex acids having cobalt in the anion are present.

3. Both the blue complex alkali thiocyanatocobaltites and the purple trihydrate of cobalt thiocyanate can be prepared by double decomposition in aqueous solution starting from the sulfate of cobalt and removing alkali sulfates by means of alcohol. This simple method avoids the use of thiocyanic acid which is not easy to prepare in at all concentrated solution and is rather unstable in aqueous solution.

4. It is shown that at laboratory temperature the trihydrate, and not the tetrahydrate, is the form stable in air for the ammonium and potassium thiocyanatocobaltites. In all other respects the statements of Rosenheim and Cohn were confirmed. Treadwell is in error as to the instability of these salts. That the purple trihydrate of cobalt thiocyanate changes into the yellow-brown hemihydrate rather rapidly when exposed to the air of an artificially warmed room has not been previously recorded.

EVAPORATION OF SOLUTIONS AND LIQUIDS IN BURETTES.

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In very accurate titrametric analyses one may weigh the amount of standard solution reacting with the constituent being determined and from the weight of solution used calculate the percentage of the constituent, providing the concentration of the standard solution has been determined upon a weight basis. This procedure avoids the possible errors arising from a change of temperature and from evaporation, if the standard solution is measured rather than weighed. The volumetric method of determining the amount of solution is, however, the one generally employed.

In the event of a distinct change occurring in the temperature of the standard solution during a determination, which means a corresponding change in the volume of the solution, one needs only to note the variation of temperature and then to consult tables for the proper correction in volume. These tables have been prepared for various solutions of various concentrations.

The error arising from evaporation of the solvent of a standard solution and the consequent increase in concentration of solute per unit volume is not so readily found in the usual works of reference on quantitative chemical analysis. The experiments reported at this time were made with the object of obtaining information regarding the rate of evaporation of solutions and liquids in burettes.

Factors Affecting the Rate of Evaporation. No previous work has been found relating directly to the effect upon the accuracy of analytical data resulting from the loss, through evaporation, of the solvent of standard solutions standing in burettes. Many papers have appeared, however, dealing with the general subject of evaporation and with the laws relating to the process,[1] but we are here concerned with a consideration only of the factors affecting the systems now being studied. From these papers just mentioned and from others dealing with certain aspects of the physico-chemical theory of solutions and liquids, a number of facts may be summarized as having a direct bearing upon the present work.

All liquids tend to assume the gaseous phase, and the measure of this tendency is known as the vapor tension of the liquid. For a given liquid there corresponds to each temperature a certain definite pressure of its vapor. This vapor pressure is defined as that pressure at which the rate of escape into the gaseous phase of the liquid molecules is ex-

[1] Livingston—Monthly Weather Report—U.S.A.—1909. "An Annotated Bibliography on Evaporation."
Vaillant—Compt. rend. *146*, 582, 811; *148*, 1099; *150*, 213.
Jablczynski and Prezmyski—J. chim. phys. *10*, 241.
Marcelin—*Ibid.*—*10*, 680.
Marcelin—Compt. rend. *158*, 1674.
Thomas and Ferguson—Phil. Mag. *34*, 308 (1917).
Burger—Proc. Acad. Sci. Amsterdam—*21*, 271 (1919).
Weiser and Porter—Jr. Phys. Chem.—*24*, 333 (1920).

"Proc. 38th Meeting, 1922 (1923)."

actly balanced by the return into the liquid phase of the gaseous molecules. In the event that the system under consideration is not closed and that the rate of escape of the liquid molecules over-balances the rate of return of the gaseous molecules, the equilibrium otherwise prevailing is disturbed and the liquid evaporates.

The rate of the process of evaporation is then subject to several variable factors. In the case of liquid water, for example, exposed in an open vessel to the atmosphere, the rate of evaporation is directly proportional to the velocity of air currents, to the radius of the exposed surface, and to the vapor tension of the liquid. The latter is in turn directly proportional to the temperature. Further, the rate is inversely proportional to the distance of the surface of the liquid from the rim of the containing vessel, to the relative humidity or partial pressure of aqueous vapor of the atmosphere, and to the barometric pressure. Various "laws of evaporation" have been proposed in the effort to connect these variables with the rate of evaporation. Some of the expressions developed include such constants as the molecular weight of the liquid and the latent heat of vaporization, if the rate is to be stated in terms of mass of liquid evaporated per unit time.

In the case of solutions there must be considered also the variation of the vapor pressure of the solvent with the amount of the dissolved solute. It is well known that the vapor pressure of a solvent is lowered by the addition of a soluble salt, for example, and that the retardation in the rate of evaporation thereby produced is proportional to the amount of salt dissolved. Furthermore, it has been shown recently that loss of solvent by evaporation of equimolar solutions is least with salts that give the greatest number of ions.

Experimental Procedure. The burettes used in this work were of the type recommended by the Bureau of Standards, and were sealed off at the bottom in order to prevent any error from leakage. Two sets were arranged, the individual members being chosen as nearly as possible with the same inside diameters. Over the "open" set was suspended a cover about 10 cm. from the ends of the burettes in order to protect them from falling particles of dust. Over the ends of the "covered" set were placed ends of test tubes, 6 cm. long, to serve as caps.

The temperature at the time of reading the burettes was taken from a thermometer suspended among them. A sling psychrometer was used for determining the relative humidity of the atmosphere according to the method of the U. S. Weather Bureau. The barometric readings are uncorrected.

Working under the conditions of experimentation stated, determinations have been made of the effect upon the rate of evaporation of (a) the size of the burette, (b) the concentration of solutions, and (c) the presence of caps over the ends of the burettes. For the study of (a) several liquids having distinctly different vapor tensions were selected—water, benzene and toluene; for (b) a series of standard solutions of sodium chloride in water were prepared by dissolving the proper weight of salt; and for (c) parallel series were run for (a) and (b)—one set covered and the other open.

For any given series of readings the burettes were filled and the solutions allowed to attain the temperature of the room. In order to have the surfaces of the solutions in the several burettes all the same distance from the top at the beginning, a siphon extending down 10 cm. from the rim was used to remove any solution or liquid above this point. After a few minutes the first reading was made. The others were taken on the mornings of succeeding days, before the small laboratory was opened and the temperature had an opportunity to change much. The sets were only partially protected from currents of air.

This method of procedure does not furnish data on the actual rate of evaporation for any definite conditions, as no attempt was made to hold any of the variable factors constant during the determinations; but it does furnish one with an approximate idea of the error involved as a result of evaporation of standard solutions under the usual conditions prevailing in the laboratory.

The following tables include the data obtained for solutions of sodium chloride of various concentrations, water, benzene and toluene. The total loss in milliliters is given for the various intervals of time.

TABLE 1. Evaporation of Liquids in Burettes of Different Capacities.

WATER

Time days	Temp. degrees C.	Relative Humidity	Barometric Pressure mm.	10 ml.		25 ml.		50 ml.		100 ml.	
				Open	Covered	Open	Covered	Open	Covered	Open	Covered
1	21.5	53	752.5	0.01	**0.01**	0.01	**0.00**	0.02	**0.01**	0.02	**0.01**
2	24.5	31	756.0	0.02	**0.01**	0.02	**0.00**	0.01	**—0.01**	0.00	**—0.02**
3	23.0	30	748.7	0.04	**0.03**	0.05	**0.02**	0.07	**0.02**	0.08	**0.02**
4	23.0	54	746.2	0.07	**0.04**	0.10	**0.05**	0.12	**0.06**	0.20	**0.10**
5	18.0	57	744.4	0.09	**0.05**	0.12	**0.07**	0.14	**0.08**	0.24	**0.12**
6	22.0	37	751.1	0.09	**0.06**	0.13	**0.07**	0.15	**0.08**	0.25	**0.13**
7	23.5	23	754.3	0.11	**0.07**	0.16	**0.07**	0.15	**0.07**	0.20	**0.08**
8	25.0	26	753.8	0.12	**0.08**	0.18	**0.08**	0.16	**0.06**	0.20	**0.06**
9	22.5	33	751.5	0.15	**0.10**	0.22	**0.11**	0.22	**0.12**	0.34	**0.16**
10	19.0	39	751.3	0.18	**0.12**	0.26	**0.13**	0.27	**0.17**	0.46	**0.26**
12	21.0	39	744.8	0.20	**0.14**	0.31	**0.16**	0.32	**0.19**	0.50	**0.30**
14	20.0	31	748.7	0.25	**0.17**	0.37	**0.19**	0.38	**0.23**	0.64	**0.36**
			BENZENE								
1	23.5	33	748.5	0.22	**0.16**	0.37	**0.20**	0.34	**0.23**	0.58	**0.34**
2	23.5	38	755.3	0.44	**0.31**	0.68	**0.39**	0.64	**0.44**	1.14	**0.70**
3	22.0	33	756.0	0.66	**0.49**	1.06	**0.64**	1.07	**0.77**	1.90	**1.30**
4	18.0	44	751.4	0.89	**0.67**	1.44	**0.91**	1.51	**1.13**	2.72	**1.96**
5	18.5	53	752.2	1.06	**0.80**	1.69	**1.05**	1.72	**1.29**	3.08	**2.22**
			TOLUENE								
1	23.5	32	753.0	0.07	**0.05**	0.10	**0.06**	0.10	**0.07**	0.16	**0.08**
2	24.0	24	746.2	0.13	**0.09**	0.18	**0.10**	0.18	**0.11**	0.30	**0.16**
3	24.0	22	747.0	0.20	**0.14**	0.30	**0.18**	0.30	**0.19**	0.52	**0.30**
4	19.0	29	752.0	0.29	**0.22**	0.49	**0.32**	0.58	**0.44**	1.02	**0.74**
Diameter of Burettes in cm.				0.86	0.86	1.08	1.08	1.06	1.06	1.24	1.24

TABLE 2. Evaporation of Aqueous Solutions of Sodium Chloride of Different Concentrations in Burettes of the Same Capacity.

Time days	Temp. degrees C.	Barometric Pressure mm.	Relative Humidity	Water		0.25 N		0.50 N		0.75 N		1.00 N		2.00 N		5.00 N	
				Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered
1	21.5	752.5	53	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.02	0.00	0.01	0.00	0.00	0.00
2	24.5	756.0	31	0.01	−0.01	0.00	−0.03	0.00	0.03	0.01	−0.03	0.01	0.04	0.03	0.05	−0.07	−0.07
3	23.0	748.7	30	0.06	0.02	0.04	0.00	0.04	0.02	0.04	0.03	0.05	0.00	0.02	0.00	−0.01	−0.02
4	23.0	746.2	54	0.11	0.06	0.09	0.04	0.10	0.05	0.10	0.08	0.11	0.04	0.09	0.05	0.05	0.03
5	18.0	744.4	57	0.14	0.08	0.13	0.07	0.13	0.09	0.14	0.10	0.14	0.07	0.12	0.08	0.09	0.07
6	22.0	751.1	37	0.14	0.08	0.13	0.07	0.14	0.09	0.14	0.11	0.14	0.07	0.12	0.08	0.09	0.07
7	23.5	754.3	23	0.14	0.07	0.13	0.05	0.13	0.05	0.13	0.06	0.12	0.02	0.09	0.02	0.02	−0.01
8	25.0	753.8	26	0.14	0.06	0.13	0.04	0.14	0.04	0.13	0.05	0.13	0.00	0.06	0.01	−0.01	−0.07
9	22.5	754.5	33	0.21	0.12	0.20	0.10	0.20	0.10	0.19	0.11	0.20	0.08	0.16	0.09	0.10	0.05
10	19.0	751.3	39	0.27	0.17	0.26	0.14	0.26	0.15	0.26	0.17	0.27	0.14	0.25	0.15	0.18	0.11
12	21.0	744.8	39	0.31	0.19	0.30	0.15	0.30	0.17	0.30	0.19	0.30	0.15	0.27	0.16	0.19	0.11
14	20.0	748.7	31	0.38	0.23	0.36	0.19	0.36	0.20	0.36	0.23	0.36	0.18	0.32	0.19	0.22	0.11
22	24.0	746.0	51	0.54	0.32	0.52	0.25	0.50	0.27	0.50	0.29	0.49	0.23	0.43	0.25	0.29	0.13
37	22.0	753.2	34	0.89	0.55	0.84	0.46	0.84	0.48	0.85	0.53	0.85	0.44	0.77	0.47	0.57	0.29
Diameter of Burettes in cm.				1.06	1.07	1.06	1.07	1.03	1.06	1.06	1.06	1.06	1.08	1.06	1.07	1.06	1.06

Conclusions. From the statements already made concerning the several variable factors involved in this work, one would predict certain of the results that are apparent in tables 1 and 2. The rate of evaporation should be greater in the 100 ml. burettes than in those of less capacity having a shorter radius of exposed surface; it should be less for water than for benzene which has, for a given temperature, a higher vapor tension; the vapor pressure of a solution 5N is less than that for one 0.25N, hence the rate should be less for the more concentrated solution; and covers over the ends of the burettes should decrease the rate, due to their partial closing of the systems and consequent prevention of freely circulating air from carrying away the gaseous molecules of the liquids.

On account of the rather complex situation prevailing in these experiments, with the several variable factors uncontrolled, it is not possible to point out the effect of each variation. It seems probable that the effects of changes in barometric pressure and relative humidity are relatively small as compared with that for changes in temperature. An inspection of the results in table 2 for the eighth and ninth days shows a small change of the former variables but a distinct increase in the readings of the burettes, even though a decrease in the temperature should have decreased the vapor tension of the water and thus have decreased the rate of evaporation. It seems evident that a change of temperature of the solutions produces a change of volume considerably larger than the change resulting from a change of vapor tension, and in the opposite direction.

It has already been stated that experiments conducted under the conditions prevailing during this work cannot give entirely satisfactory results, but they do furnish a general basis for predicting what may happen when such measurements are made in the usual laboratory. It is evident that caps on burettes do retard the rate of evaporation; but it is also evident that the total loss through evaporation for an aqueous solution is small at the end of a day, even in the open burettes, and one never takes such a length of time for the ordinary titration. Changes of temperature are liable to cause a much greater change in the volume of a standard solution.

THE USE OF SOLUTIONS OF INORGANIC SALTS AS PERMANENT COLOR STANDARDS.

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In the colorimetric determination of certain substances a common procedure consists in comparing, by means of a colorimeter or some other device suitable for the desired accuracy, a definite volume of a solution containing the unknown substance with various standard solutions containing definite amounts either of the constituent being determined, or of some other substance showing the same color as this constituent. When a match is found between the unknown and one of the standards, it is assumed that the amounts of the color-forming constitu-

ent in the two solutions are identical, if of the same composition, or equivalent to each other, if of different compositions. Where frequent determinations are to be made in this manner, it is very desirable to have permanent standards for either of the cases mentioned. Loss of time results if one must prepare a new set for each day or determination; and one's work is uncertain if the colors of the standards change or fade following some reaction affecting the color-forming constituent.

The synthetic organic chemist has supplied us with compounds of every desirable shade of color which might be useful in the preparation of such standards. Unfortunately, many of these compounds do not maintain their color indefinitely when in solution and exposed to the light. In some the color fades; in others the colored solute coagulates and settles out, leaving the solution clear.

In the effort to avoid the difficulty arising from such instability of color with organic substances, occasional work has been done for a number of years involving the use of solutions of inorganic salts. The purpose of the present paper is to review the information available regarding the color of solutions of inorganic substances, to note the requirements of a permanent color standard and the limitations of inorganic substances for such purposes, to mention some of the possible combinations for permanent standards, and to present a résumé of previous work upon the subject. Experimental work is under way relating to certain colorimetric standards but sufficient data is not yet available for any definite conclusions.

The Color of Inorganic Substances in Solution. Compared with the amount that has been written concerning the color of organic compounds, there is a relatively small amount available regarding the color of inorganic compounds. Particularly is this true both for the actual colors of the solutions of the compounds and also for the permanency of such colored solutions.

Recently Bichowsky[1] has discussed the color of inorganic compounds from the standpoint of electronic structure and valence of the atoms. The color exhibited by any compound is the result of its selective absorption of light, and only those substances are capable of such absorption which have an arrangement of electrons free to vibrate in the proper manner. He points out that compounds of invariant valence elements are colorless, due to their high electron stability and consequent absorption of light of short wave lengths—the ultraviolet. According to Bichowsky's table of valence colors for the elements of variable valence, the chief elements we may expect to show color (omitting the rare earth elements and the oxides and sulfides of the variable valence elements) are copper, gold, (silver), titanium, vanadium, chromium, molybdenum, tungsten, uranium, manganese, iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium, and platinum.

In figure 1 is given Mellor's adaptation of the periodic table as arranged by Bayley, in which the atomic weights and the atomic numbers of the elements have been included. The elements of invariant valence (forming colorless compounds) have been indicated with a cross.

[1] Jr. Am. Chem. Soc. *40*, 500 (1918).

Those forming compounds with pronounced colors are inclosed in the circles. It is of interest to note in connection with the latter series of elements that, (a) the most common ones have the consecutive atomic numbers 22 to 29; (b) two other series of consecutive numbers are included; (c) all the transition elements are included; and (d) those not in the transition elements are substantially the ones adjacent to them. Although there are some colored compounds of the elements not already mentioned, it is probable that few of them will prove of value for the preparation of colored solutions.

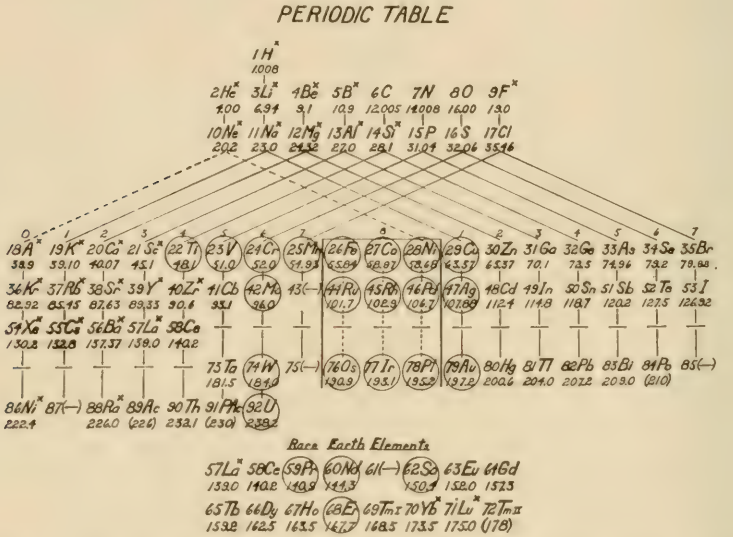

Fig. 1. Showing the location in the periodic table of the chief elements forming colored compounds.

Requirements of a Satisfactory Permanent Color Standard. Any solution to be considered as a possibility for a permanent color standard must first of all possess a color suitable for the purpose in hand, or be capable of giving it through proper blending. The color must be uniform throughout the solution and must not change in intensity or hue. To be suitable for general use the color must be such as to be accurately and readily reproducible. Furthermore, if two or more solutions are to be mixed in order to obtain some blend of the original colors, the solutes and solvents must be of such a nature that no reaction occurs on mixing which destroys the expected, resultant color. The intensity of the color must be sufficient—this requirement would practically eliminate the use of such compounds as manganous salts whose color in solution is very definite but relatively low in intensity. In general it is desirable to have dilution of a colored solution result merely in a decrease in intensity of the color rather than in a real change of color[2].

[2] Sheppard—Photo-Chemistry, p. 153, 159 (1914).

Limitations of Inorganic Compounds. When one attempts to select a set of solutions of inorganic materials whose colors include the seven primary, visible colors of the solar spectrum, he is at once confronted with an inherent scarcity of individual colors of a wide variety. The range is fairly well covered from the red of an aqueous solution of cobaltous chloride to the blue of an aqueous solution of cupric sulfate. These, however, do not include deep reds on the one end nor deep blues, indigos nor violets on the other. As will be noted later, deeper reds and blues may be obtained under certain conditions but the stability of the solutions has not been found entirely satisfactory. Some solutions have good colors but cannot be mixed with others, which makes their use limited.

While at certain times one may obtain a closely agreeing match between an unknown, colored solution and an inorganic permanent standard, at other times such a match may be difficult to accomplish, as in tests on such complex systems as the usual surface water. On the one hand, pure or mixed solutions show a clearness and brilliancy of color which many complex samples do not possess. On the other hand, the color produced in the solution to be tested may depend upon a variety of conditions, such as temperature, quantity of reagent added, manner of making reagent, variable quantity of accompanying substances, time elapsing after the preparation of the sample before comparison of the color, and others practically impossible to control closely. Uniformity in preparation and handling both of sample and standard are necessary in such cases.

Elevation of the temperature often changes the color of absorbing media[3]. It is well known, for example, that the red color of an aqueous solution of cobaltous chloride turns blue if the temperature is raised sufficiently. Another red solution, matching the color of the first but having a different composition, probably would not show the same change of color on passing through the same changes of temperature. When such a change of temperature causes a chemical modification, changes in the absorption spectrum occur; but in chemically stable systems, such as potassium bichromate, the alteration is small or nil.[4].

Another difficulty presents itself. It seems probable that, if one matched the green of a solution of nickelous sulfate with a green produced by blending solutions of cobaltous chloride, ferric chloride and cupric sulfate, the mechanism giving rise to the same color sensation in the two cases for one individual would not do so for another[5]. Arny[6] has found, for the conditions he studied, that several individuals obtained the same Lovibond readings on a number of different solutions; but Watson[7] states that the color sensation produced in different persons by the same quality of light may vary considerably.

Besides the effect of a change of temperature just mentioned, several

[3] Wood—Physical Optics, p. 441 (1911).
[4] Sheppard—*Loc. cit.*, p. 163.
[5] Richards and Ellms—Jr. Am. Chem. Soc. *18*, 75 (1896).
[6] Arny—Report 8th. Intr. Congr. Appl. Chem. *26*, 319 (1912).
[7] Watson—Textbook of Physics, p. 559 (1919).
Sheppard—*Loc. cit.* p. 150.

other factors may affect the permanency of the color of a solution. Among these may be mentioned the possibility of changing a color's hue or intensity, or both, through the reaction of the solvent and the solute, through the action of the solvent on the container, or through the action of light upon the solution. Many qualitative observations have been made bearing upon these reactions, but little data of a quantitative nature is available.

In discussing the photo-sensitiveness of salts of metals, Sheppard[5] states that "the greater proportion of ordinary crystallizable salts of the metals, whether in the solid state or dissolved, are comparatively stable in respect to light. But this stability is certainly relative rather than absolute, being an inverse function of the absorption of light of the bodies, and is, practically, not disconnected with the fact that it is rare for these bodies to be exposed without intermission. . . . It has been observed that aqueous solutions of the salts of the heavier, polyvalent metals undergo a gradual change of character on keeping. This change is apparently of the nature of a hydrolytic cleavage of the metal salt, leading by a series of reactions in stages, with concomitant side reactions fixing each stage enduringly and irreversibly as evolved, to the deposition of structurally conformed aggregates of insoluble oxides, sulfides, and ternary and quaternary complexes of varying composition."

Inorganic Substances Available for Colored Solutions. There are recorded many more or less isolated statements to the effect that various inorganic substances give a certain color in a given solvent, but no general summary or collection of such data has been found. Many of these colors, and particularly certain of those used as qualitative tests, are too transitory to merit consideration in this paper. Others are apparently permanent for a considerable period of time. The original intention was to present a list of those which seemed to offer the most promise of meeting the requirements already stated. The time available has proven too limited for the accomplishment of this compilation; but mention will be made of some of the types of substances which seem to have possibilities, even though their application may be limited. The solutions mentioned are at present being investigated. It is hoped that special apparatus will be available later so that quantitative data may be collected for them.

Aqueous solutions seem to be by far the most important. Those containing the color-forming elements mentioned in connection with the periodic table, in the form of simple cations, include our most familiar, colored solutions, such as cupric sulfate, ferric chloride, etc. The color of some of these solutions is markedly changed through the formation of complex cations under certain conditions, as the strongly ammoniacal solutions of cupric, cobaltic, and nickelous salts. It should be mentioned that pronounced changes of color of solutions of salts of some of the elements takes place on changing the solvent from 1 per cent hydrochloric acid to 30 per cent acid. The most common anions giving colored solutions are chromate, dichromate, permanganate, ferrocyanide, ferricyanide, and chloroplatinate.

[5] *Loc. cit.* p. 318.

Little can be stated at present regarding the colors of non-aqueous solutions of salts of the color-forming elements. In some cases there is a profound change in the color with the change from water as the solvent, as, for example, the change from the red of cobaltous chloride in aqueous solution to the deep blue with the salt dissolved in absolute ethyl alcohol. A solution of the same salt in acetone is a deeper red than an aqueous solution. A number of these solutions are being investigated.

A very limited class of solutions consists of those in which the elements as such are dissolved. A saturated, aqueous solution of bromine in water has a marked orange-red color. Iodine in carbon tetrachloride gives a beautiful pink colored solution, while in ethyl alcohol it shows a yellowish color. In certain other solvents these elements give somewhat different colors.

Certain colloidal systems consisting of a solid dispersed through a liquid show marked colors, such as the red of ferric hydroxide in water. It is distinctly questionable as to whether such a system would be of any value for permanent color standards.

Previous Work. An attempt has been made to collect the references relating to the use of solutions of inorganic salts as permanent color standards. The following résumé includes a statement of the principles and methods involved in the work for which reports have been located.

Crookes, Odling and Tidy[9] devised an instrument for comparing the colors of waters with solutions of inorganic salts. This instrument consisted of a pair of 24-inch tubes, one of which contained the water under examination, while the other remained empty. Behind the latter were placed two hollow wedges, one containing a 1 per cent solution of cupric sulfate, the other a solution of ferric and cobaltous chlorides containing 0.7g. of iron and 0.3g. of cobalt per liter, with a slight excess of free hydrochloric acid. These wedges were pushed over the empty tube until their color matched that of the water under examination in the other tube, and the color was recorded as equal to so many millimeters of blue and red solutions.

Hazen[10] proposed the use of a mixture of potassium chloroplatinate and cobalt chloride as a color standard for natural waters. The stock solution contained 1.246g. of potassium chloroplatinate (0.5g. Pt) and 1g. of crystallized cobaltous chloride (0.25g. Co) and 100ml. of concentrated hydrochloric acid, the whole being diluted to one liter. Solutions for comparison were made by diluting 1, 2, 3, . .ml. to 50. This solution was found to be unaltered after one year, even when standing in the light.

Jackson[11] reported the use of permanent color standards for the colorimetric determination of several constituents in water. The various standards used consisted of mixtures of solutions of the following salts:

[9] Chem. N. *43*, 174 (1881).

[10] Am. Chem. Jr. *14*, 300 (1892).
A.P.H.A.—Standard Methods of Water Analysis, p. 9 (1917).

[11] Tech. Quar. *13*, 314 (1900).
A.P.H.A.—*Loc. cit.* p. 17 (1917).

for ammonia, potassium chloroplatinate (2g. per L.) and cobaltous chloride hexahydrate (12g. per L); for nitrites, cobaltous chloride hexahydrate (24g. per L.) and cupric chloride dihydrate (12g. per L.); and for iron, cobaltous chloride hexahydrate (24g. per L.) and potassium chloroplatinate (12g. per L.). In the preparation of each solution the salt was dissolved in water, 100ml. of concentrated hydrochloric acid added, and the whole diluted to one liter.

Kendall and Richards[12] discussed the factors preventing a perfect match between permanent color standards and the colors obtained with many samples of water. As standards for routine work they do recommend the use of a neutral solution of potassium chromate in connection with the Grandval and Lajoux test for nitrates, and of various dilutions of Tidy's formula (0.25g. potassium dichromate and 9.05g. cobaltous sulfate heptahydrate per L.) for the determination of ammonia.

Washburn[13], by combining "in the proper proportions" solutions of ferric chloride, cobaltous nitrate and cupric sulfate, prepared permanent color standards for use in determining the proper iodometric end point in the determination of arsenious acid.

McBain[14], in his study on the use of phenolphthalein as an indicator, employed as permanent standards solutions containing mixtures of copper and cobalt salts, acidified with nitric acid to prevent hydrolysis. The most dilute solution contained 0.50g. cobalt nitrate hexahydrate and 0.62g. cupric sulfate pentahydrate per liter; the others contained 2, 3, etc., times these amounts. The difference between any two standards was planned to be equivalent to the color change caused by the addition of one drop of N/250 acid or base.

Arny[15], following Washburn's suggestion for blending solutions colored by the cobaltous, ferric and cupric ion, proposed the adoption of solutions containing these ions as "international standards for colored fluids". By mixing these three primary colors, red, yellow and blue, in the proper proportions he obtained 88 blends, ranging from the red through to the blue. These solutions are designated as the "Co-Fe-Cu" standards. In the preparation of the standards, 0.5 N solutions were made of cobaltous chloride, ferric chloride and cupric sulfate by dissolving the salts in 1 per cent hydrochloric acid. All of the work was checked by means of a Lovibond tintometer, and the acidified solutions were found to give the same readings after standing for a year.

Arny and Pickhardt[16] discussed the requirements of satisfactory color standards and reported further observations on the "Co-Fe-Cu" series proposed earlier. This series lacks deep reds and deep blues.

Arny and Ring[17], in the effort to provide for the deficiencies of the "Co-Fe-Cu" series, proposed a new series of 0.1 N ammoniacal solutions of chloropentammine cobaltic chloride (red), ammonium chromate (yel-

[12] Tech. Quar. *17*, 277 (1904).
[13] Jr. Am. Chem. Soc. *30*, 31 (1908).
[14] Jr. Chem. Soc. *101*, 814 (1912).
[15] Report 8th Intr. Congr. Appl. Chem. *26*, 319 (1912).
Jr. Am. Pharm. Assoc. *2*, 76 (1913).
[16] Druggist's Circular *58*, 131 (1914).
[17] Jr. Franklin Inst. *180*, 199 (1915).

low) and ammonio-cupric sulfate (blue)[18]. When mixed in various proportions, these salts were found to produce all hues except a few delicate pinks and violets. The tints which could not be produced by this "Co-Cro-Cu" series were obtained by means of mixtures of 0.001 N potassium permanganate and 0.01 N potassium dichromate, known as the "Cro-Mn" series. In the "Co-Cro-Cu" series the red and yellow solutions were found to remain unchanged in color if kept well stoppered. The blue solution, however, precipitates within a few weeks and must be prepared frequently. In the "Cro-Mn" series each solution is stable alone, but they begin changing an hour after mixing.

Arny and Ring[19] reported further use of the above mentioned solutions in connection with certain pharmaceutical work.

Arny and Ring[20] reported the application of the three series of solutions in the preparation of permanent standards for use in the colorimetric determination of ammonia, nitrates, nitrites, vanillin, uric acid, salicylic acid and phosphates. They state that practically every tint desired in colorimetric work can be obtained with the three series of colors. The original acidified "Co-Fe-Cu" solutions and their blends neither fade nor precipitate until at least two years old; the ammoniacal cobalt and chromate solutions show no fading after a year. The ammoniacal copper solution precipitates and undergoes change of color within a few weeks, but the blends keep satisfactorily when sealed in ampules or kept in well filled, rubber stoppered bottles which are not opened. The concentration recommended in this paper for the "Co-Cro-Cu" series is 0.02 N.

Arny, Kish and Newmark[21] discussed the unreliability of the Lovibond tintometer for the testing of cottonseed oil, and proposed the use of the "Co-Fe-Cu" and "Co-Cro-Cu" color standards.

Kolthoff[22] was the first to propose the use of permanent color standards instead of the usual buffer solutions and indicators in the colorimetric determination of hydrogen ion concentration. By means of M/4 cobaltous nitrate and M/6 ferric chloride he prepared solutions which match the colors of buffer solutions through the pH range of certain indicators. Matches were made showing the change in color of neutral red, methyl orange, tropaolin 00 and partially for methyl red.

Snell[23] recommends the use of Arny's "Co-Fe-Cu" series for the preparation of permanent standards for the colorimetric determination of carbon, lead, chlorine, and possibly for aluminium. He states further, that for the determination of bismuth, permanent standards may be made using the same reagents as in the case of the unknown sample. Solutions of potassium chromate, potassium chloroplatinate and ammoniacal cupric chloride may be used for permanent standards for the determination of chromium, potassium, and oxygen, respectively.

[18] Note—Salts of copper and cobalt are M/20 and the dichromate M/120.
[19] Jr. Am. Pharm. Assoc. *4*, 1294 (1915).
[20] Jr. Ind. Eng. Chem. *8*, 309 (1916).
[21] *Ibid. 11*, 950 (1919).
[22] Pharm. Weekblad *59*, 104 (1922).
[23] Colorimetric Analysis (1921).

AN IMPROVED MUREXIDE TEST FOR TEACHING PURPOSES.

Samuel E. Earp, Indianapolis, Indiana.

During my class work in chemistry in medical college I directed my students to follow Hoffmann and Ultzmann as a laboratory guide. Directions for the murexide test were as follows: Mix concretion in a small mortar, place in a porcelain dish, add a few drops of nitric acid and a little water and warm carefully over a flame until the uric acid is dissolved. Evaporate cautiously, almost to dryness. Already we notice during the evaporation, if uric acid is present, onion-red streaks on the walls of the dish which vanish suddenly if that portion of the dish approaches the flame. If, when the fluid has evaporated to dryness, we add a drop of ammonia to the residue the whole interior of the dish becomes a beautiful purple-red (murexide acid-purpurate of ammonia). If KOH is added to the residue it becomes violet-blue. The murexide depends upon the fact that by the addition of HNO_3 and heat, first alloxan and then alloxantine is formed which on addition becomes murexide.

It is very commonplace for 50 per cent of the class to make failures. It seems difficult for them to gauge the proper amount of dilution and the requisite amount of heat. I adopted the following method without more than two per cent of failures.

Heat the concretion slowly in an evaporation dish with a minimum amount of water acidulated with nitric acid until the approach of dryness. Put metal plate over low flame burner frame and upon it a moistened salt of ammonium; then invert the evaporating dish over the ammonium so that the fumes are confined. This operation is quickly accomplished and there is little opportunity for error and too, even a student who is a novice, will not fail in this method of demonstration.

"Proc. 38th Meeting, 1922 (1923)."

FOG FORMATION IN AIR WHICH HAS PASSED THROUGH A SILENT DISCHARGE.

By F. O. Anderegg and K. B. McEachron, Purdue University.

The corona discharge has been studied in the Chemical Laboratory[1], [2] and Electrical Engineering Experiment Station[3], [4] of Purdue University with especial reference to the formation of nitric acid and ozone in air. One of the more interesting of the phenomena observed while working under a large variety of conditions has been the formation of fog in the air passed first through a discharge and then through a solution for the absorption of the nitric acid anhydride or the ozone formed in the discharge. An important connection between fog formation and the yield of nitric acid was suspected. This led to a study of fog formation in the corona work during a period of several years, the results of which are recorded here.

A fog, in the first place, may be defined as the suspension of finely divided particles of liquid, (or frozen liquid if the temperature is low enough), in a gas. In order to have a fog there must be moisture in the atmosphere, usually approaching the saturation point. There must be also nuclei on which the fog may be condensed because it has been shown that in the absence of all nuclei a large supersaturation is required to condense the water[5]. Nuclei may be dust particles, ions[5] or chemical substances of a hygroscopic character[6]. The absence of dust particles sufficient to cause formation under the conditions used is shown by the fact that during the sweeping out of the apparatus preliminary to discharge no fog was observed at any time. Ions did not serve as nuclei for the following reasons: C. T. R. Wilson[5] shows that a certain amount of supersaturation is necessary before water vapor will condense on ions. Passing the air coming out of the discharge tube through a large electrostatic field failed to have any effect on the fog either before or after the discharge was turned on.

There remain as nuclei only hygroscopic compounds. That it was due to the chemical substances was proved by dividing the stream of air after leaving the discharge. One-half passed directly into the absorption system and fog was observed as usual. The remainder of the gas passed through a large tube containing asbestos impregnated with silver so that the ozone was decomposed completely and the nitrogen pentoxide reacted with the silver oxide so formed to produce silver nitrate[4]. The air then passed through an absorption apparatus and gave no evidence of either ozone or oxides of nitrogen or fog. Ozone alone in contact with moisture has a slight tendency to produce ioniza-

[1] Anderegg. J. Am. Chem. Soc. 39, 2581 (1917).
[2] Ray and Anderegg. *Ibid.* 43, 967 (1921).
[3] Harding and McEachron. J. Am. Inst. Elec. Eng. April, 1920.
[4] McEachron and George. Purdue Univ. Eng. Exp. Sta. Bull. 9.
[5] C. T. R. Wilson. Phil. Trans. 189A, 265 (1897); 193A, 289 (1899).
[6] Bancroft. J. Phys. Chem. 22, 312 (1918).

"Proc. 38th Meeting, 1922 (1923)."

tion and to cause fog formation[7]. In working with pure oxygen it is possible to secure conditions such that a slight fog is produced on ab-

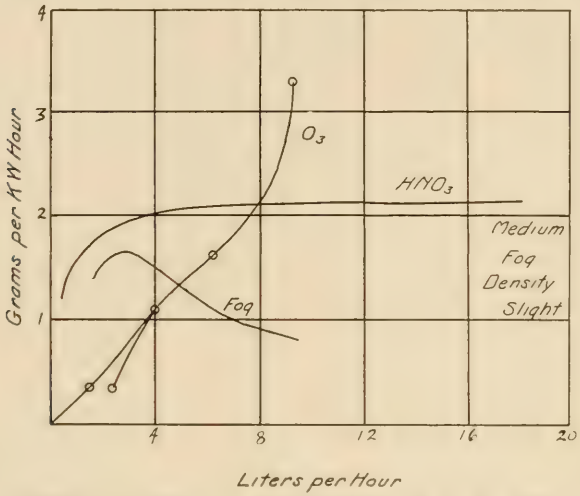

Fig. 1. Formation of nitric acid, ozone and fog in air at 460mm. pressure in a very large discharge apparatus at more than 50,000 volts. The nitric acid curve is given as figure 8 by Harding and McEachron, cit. 3. The other curves have not been published.

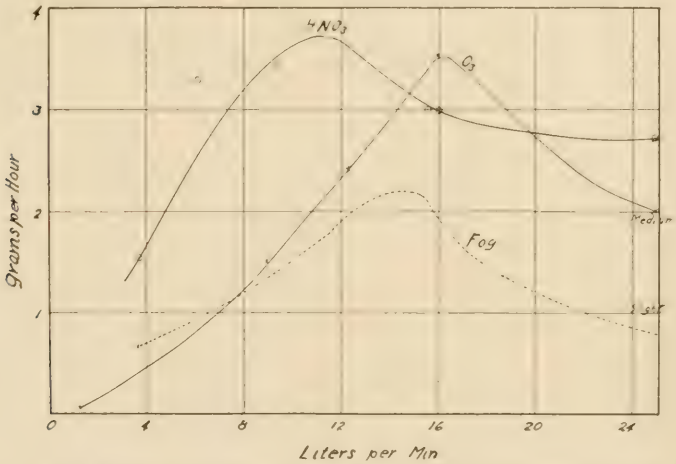

Fig. 2. The same tube was used as in figure 1, but the pressure of the air was 560mm.; cf. figure 9, cit. 3.

sorbing the ozone in potassium iodide solution. But the fog produced by the ozone alone was a very small part of the total observed. That leaves the nitrogen pentoxide which is, like sulfur trioxide, a very hygro-

[7] Pringal. Ann. Physik. 26, 727 (1908). Pringal's explanation is obviously wrong because ozone will not react with unactivated nitrogen, cf. Bieber. ibid. 39, 1313 (1912).

scopic substance. Its ability to condense moisture is indicated by the titration of the fog collected from a small Cottrell precipitator. The acid so obtained had a concentration approximately normal.

Nitric oxide (NO) is first formed in the discharge. This combines quantitatively with the ozone which is also present unless the temperature is too high, to give the nitrogen pentoxide. According to this reasoning those conditions which give the maximum product of the concentrations of ozone and of nitrogen pentoxide should produce the most fog. The curves given, figures 1, 2 and 3, which are typical of a very

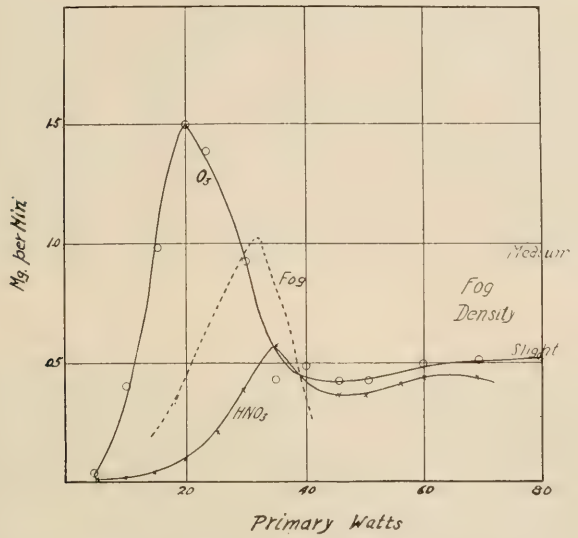

Fig. 3. The formation of ozone, nitric acid and fog in air which was undergone discharge in contact with fragments of quartz glass; cf. Anderegg and Bowers, A Type of Silent Discharge Involving Catalysis, page 177.

large number of similar curves, indicate the validity of this reasoning.

It was observed that the fog developed to a maximum during the course of a run and then gradually diminished in strength at a rate which depended upon the flow rate of the air. The cause for this was the cooling effect of the evaporation of moisture into the air reduced the temperature sufficiently to lower the amount of moisture evaporated below the condensation point.

The reason for the passage of these fume particles has been explained by Bancroft[2] as due to the adsorption of a layer of air on the surface which acts like a cushion to prevent the droplet of nitric acid solution from coming in contact with the alkaline absorbing liquid.

[1] Wulf, Daniels and Karrer. J. Am. Chem. Soc. 44, 2402 (1922).

[2] Bancroft. Applied Colloid Chemistry, pp. 65-78 (1921).

AN OSCILLOGRAPHIC STUDY OF AN INDUCTION COIL WITH HIGH FREQUENCY LOAD.

F. O. Anderegg and K. B. McEachron, Purdue University.

A report was made to this Academy a year ago on a Chemical Study of a High Frequency Corona Discharge[1]. During the preliminary work a large induction coil capable of throwing a 40 cm. spark was connected to the Tesla coil as described in that reference. The source

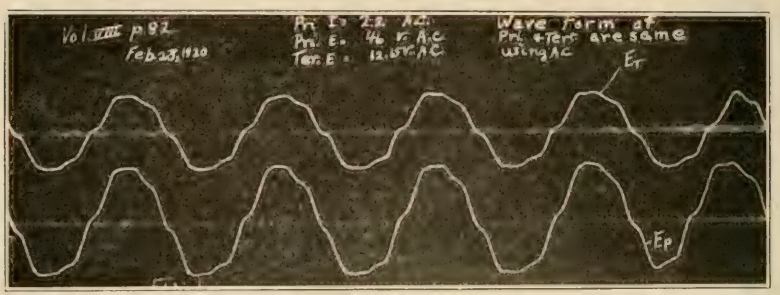

Fig. 1. An oscillograph showing that the wave form of the voltage from a tertiary coil wound outside of the secondary coil of an induction coil is the same as the alternating voltage impressed upon the primary coil, all three coils being concentric.

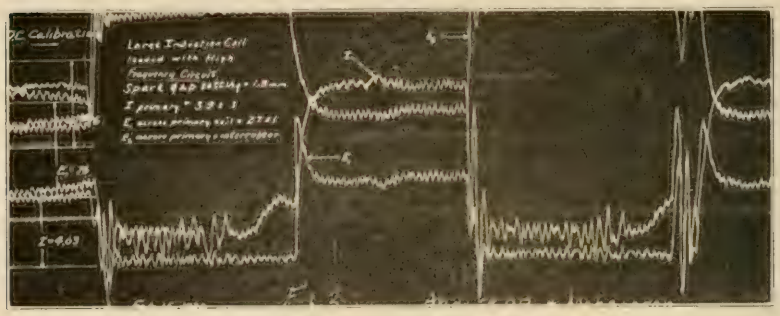

Fig. 2. The wave forms of the current and voltages of the primary circuit of a large induction coil. The current was supplied by an 8-pole d.c. generator, explaining the small waves.

of supply for the primary of the induction coil was the campus direct current at 100 v. The yields of ozone obtained with this arrangement were very unsatisfactory as to consistency of results. Later, a transformer was used in place of the induction coil with much better results. A General Electric oscillographic apparatus being available, a study was made of the induction coil to see if the variations could be explained.

The secondary current could be obtained directly with the aid of a sensitive element. To get the secondary voltage a tertiary coil was

[1] Proc. Ind. Acad. Science, 1921, p. 157.

"Proc. 38th Meeting, 1922 (1923)."

wound around the outside of the secondary and the ratio between the secondary and tertiary was determined with a standard spark gap. The ratio was 440:1. Figure 1 shows an oscillograph of the primary and tertiary voltage waves and it is seen that the two forms are identical as would be expected, when it is remembered that the winding in the induction coil consists of a primary coil wound on the magnetic core

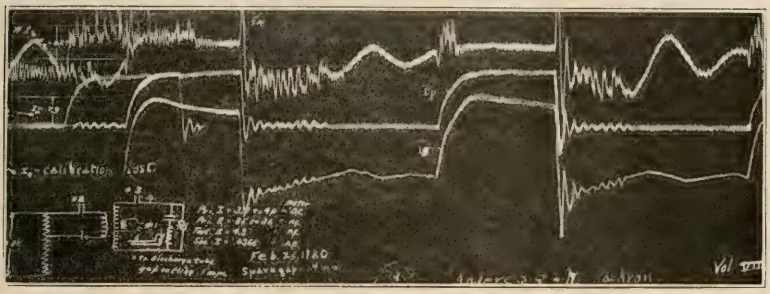

Fig. 3. The induction coil was loaded with a high frequency discharge. The peculiar character of the tertiary voltage wave is noteworthy. Note the considerable part of the wave below the zero line indicating reversal of voltage.

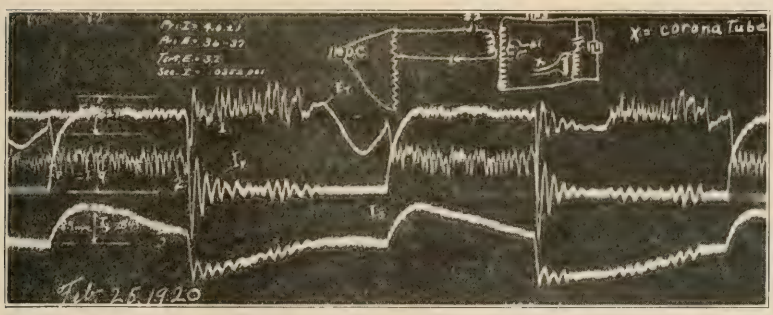

Fig. 4. Same as figure 3. Note the alternating character of the secondary current and of the tertiary voltage. These oscillographs indicate the marked deviation from unidirectional current usually associated with the induction coil.

around which is the secondary and finally the tertiary is wound outside of that.

The other figures, 2, 3, and 4, are self-explanatory. The voltage and current waves are far from being even uni-directional. Attention is called to the peculiarities of the tertiary voltage wave. From the oscillographs it is not to be wondered that the chemical effects, which are so sensitive to small voltage charges, are so inconsistent.

A TYPE OF SILENT DISCHARGE INVOLVING CATALYSIS.

F. O. Anderegg and E. H. Bowers, Purdue University.

The complications occurring at the solid surfaces in contact with electrical discharges are not generally appreciated. As a result of considerable study of chemical reactions in corona discharges the fact that the solid-gas interface introduces variable factors has become more and more evident. From a knowledge of the phenomena involved in contact catalysis it has become increasingly clear that these two apparently unrelated phenomena may be interdependent. The result of this dawning consciousness has led to a study of catalysis in chemical reactions in corona discharges, the first report of which is given here.

The theory of the action of a dielectric material in an electric field was first given by Faraday[1], who showed that the attraction between charged bodies is inversely proportional to the dielectric constant of the

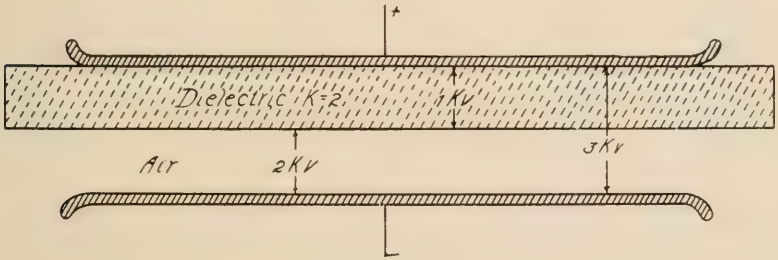

Fig. 1. The interposition of a dielectric material of constant 2 has increased the potential drop in the remaining air space from 1.5 to 2 Kv.

material separating them. Then, when equipotential lines are drawn (normal, of course, to the lines of force), they will be spaced in proportion to the dielectric constant of the material used. The term, specific inductive capacity, is more illustrative of the effect but its length militates against its use. If sheets of dielectric material, such as glass, are placed against one or both of parallel electrodes without filling the whole space between them, there will be a distribution of equipotential lines as given in figure 1. The equipotential lines are close together in the gas filled space so that there is a large potential gradient in the gas. It may be helpful to remember the analogy to contour lines on a map. If the potential is sufficient the gas "breaks down", that is, some of the molecules are ionized and a silent or corona discharge is set up. The presence of solid dielectric *tends* to prevent sparking or arcing over, so that with a suitably designed apparatus it is possible to fill the whole of the space with a corona of high density. If a rod of glass or other dielectric material is placed between parallel electrodes the effect of the lines of force is as given in figure 2[2]. On placing two

[1] Jeans. Electricity and Magnetism. 4th Ed. pp. 126-135 (1920).

[2] Jeans, loc. cit., p. 228.

rods in contact it is seen (figure 3) that the space of closest contact is one of high potential gradient. This device of using glass rods in an electric field has been tried out at Purdue by K. B. McEachron[3], who has obtained some high yields of ozone.

Similar reasoning would show that a sheet of dielectric material between two parallel electrodes would produce no distortion of the field. This theory has been tested experimentally by C. W. Rice[4] using glass cylinders with experimental conditions such that there were no "end effects". It was found that the presence of the cylinder always lowered the arc-over voltage. The condition of the surface and especially the nature of the gas or vapor adsorbed on it were found to have important effects. Moisture is always very potent in aiding the arc-over[5]. These observations led to the idea that the mechanism of this promotion of arc-over was catalytic in nature. Just as solid surfaces promote chemical reactivity by adsorbing the reacting substances and activating them by loosening their bonds so here the adsorbed molecules

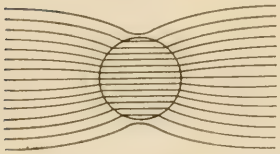

Fig. 2. The lines of force in an electric field are distorted by a rod or sphere of dielectric material.

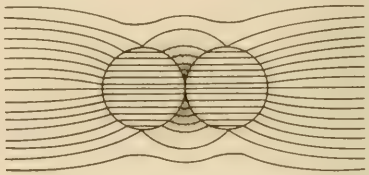

Fig. 3. Two such bodies in contact distort the lines of force as shown. The maximum discharge in the gas occurs in the shaded areas.

in an activated condition would be much more easily ionized and would aid materially in establishing a path of discharge[6].

For this catalytic action of promoting creepage along the surface the name, "creepage corona" is proposed. In any discharge involving dielectrics there will be two effects, that of the specific inductive capacity in increasing the discharge density and the creepage action in increasing the discharge current. In addition, the purely catalytic effect on any chemical reactions of the solid-gas interfaces will produce effects which

[3] McEachron and George. Purdue Univ. Eng. Exp. Sta. Bul. No. 9. pp. 58-108 (1922).

[4] C. W. Rice. Trans. Am. Inst. Elec. Eng. 36, 1947 (1917).

[5] This action of moisture is due to the polarity of the water molecule. Replacing the polar water with nonpolar oil lowers the creepage effect and raises the arc-over potential.

[6] G. V. Hevesy. Z. Physik. *10*, 80-3 (1922), who found that small crystalline conglamerates had fifty times the conductivity of large crystals, explains the results as due to "loosened spots" in the crystal lattice which would result in an irregularity in the order of the ions especially at the surfaces. H. S. Taylor. Chem. Age. *30*, 309; J. Franklin Inst. *194*, 1 (1922), explains the catalytic action of reduced copper on the reduction of copper oxide at the point of contact of the two phases, as due to a distortion of the adsorbed reducing gas when in contact with the different electronic configurations in the two phases.

superimposed on the other, are apt to be rather too complicated for theoretical treatment. The conclusion that the effects are in large part catalytic, is seen to be justified from the following experiments.

EXPERIMENTAL. A Liebig condenser forms a convenient laboratory apparatus for testing the effects of different dielectric materials upon various combinations of gases. The outer jacket with its cooling water running through serves as one electrode and it is convenient to use an aluminum wire at the axis of the tube for the other electrode. Aluminum is covered with a very coherent coating of oxide which decreases its catalytic activity, apparently as far as the corona discharge is concerned. A small experimental transformer with the ratio of 120:1 was used and the connections are given in figure 4. The power actually supplied to the tube has not been determined in these first experiments. The secondary voltage was simply obtained from the transformer ratio

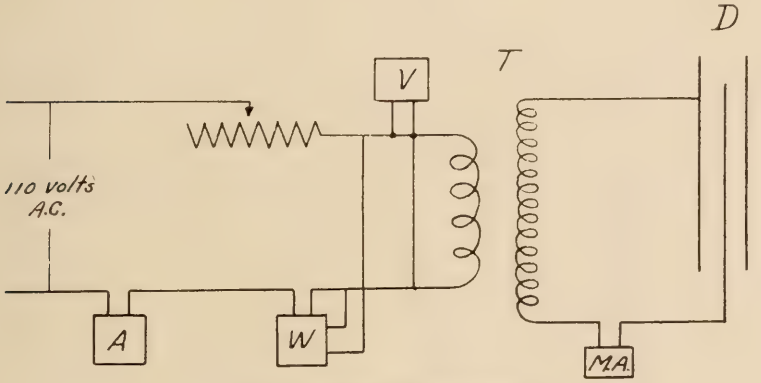

Fig. 4. Diagram of connections.

and the reading of the voltmeter. Air, carbon monoxide and mixtures thereof freed from carbon dioxide and moisture have been studied. The arrangement of the apparatus is indicated in figure 5.

The dielectric materials experimented with have included fragments of ordinary glass rods, of quartz glass, of earthenware (clay marbles) with and without impregnation with beeswax. Crystalline hematite, as well as white and blue flint were also used in addition to glass wool. Some experiments were made with no fragments of dielectric material around the inner wire electrode. The actual density of the space when packed with glass fragments was twice that when packed with glass wool. The surface of the glass wool, was however immensely the greater, resulting in enhanced chemical effects.

Some of the curves obtained for ozone formation[7] in air are given in figure 6 while figure 7 gives similar results for nitric acid yields. Figure 8 gives typical curves for the simultaneous production of both ozone and nitric acid in contact with white flint. With the increase in

[7] Proc. Ind. Acad. Sci. 1921, p. 159, for details of analysis.

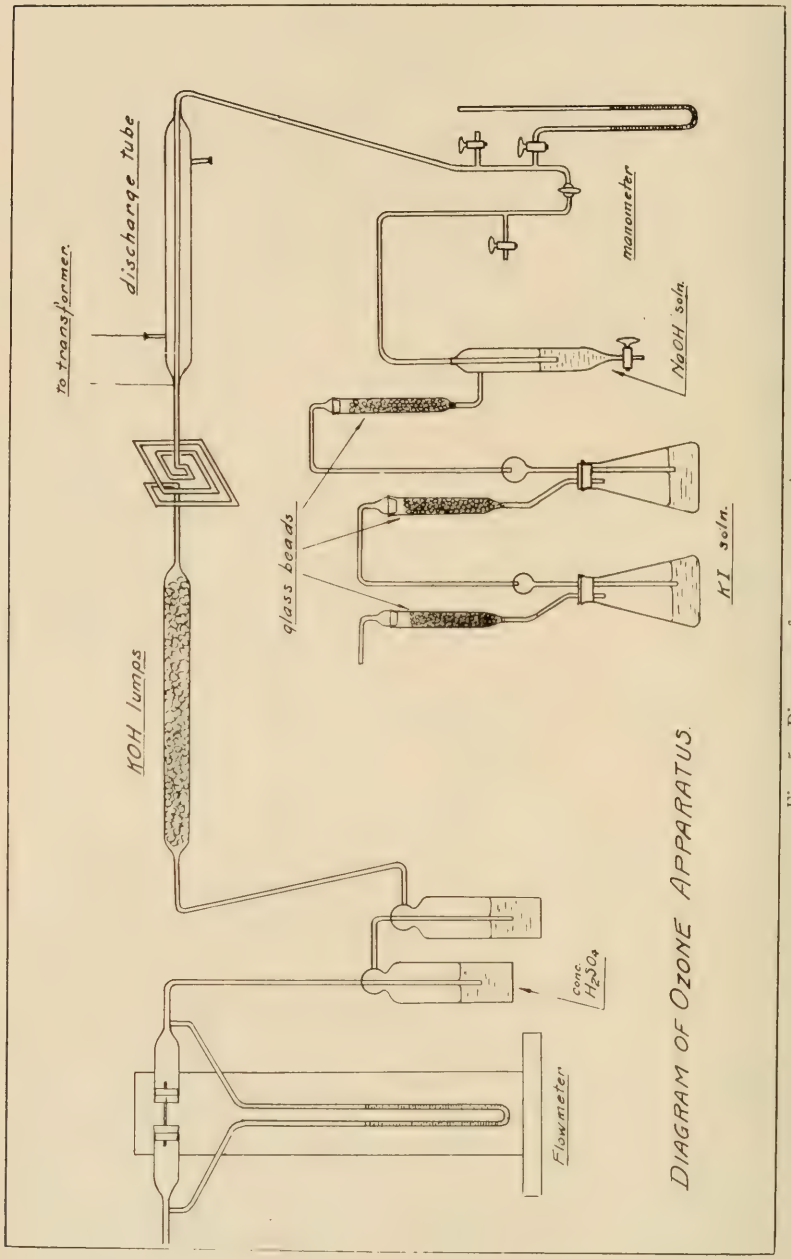

Fig. 5. Diagram of ozone apparatus.

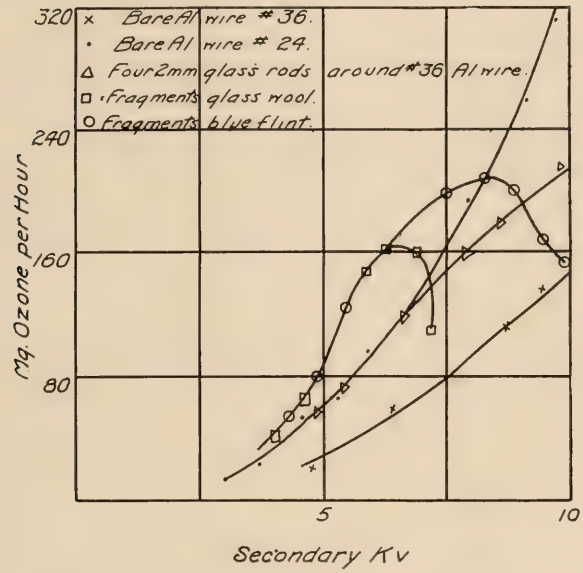

Fig. 6. Ozone formation with and without fragments of dielectric material in contact with the discharge.

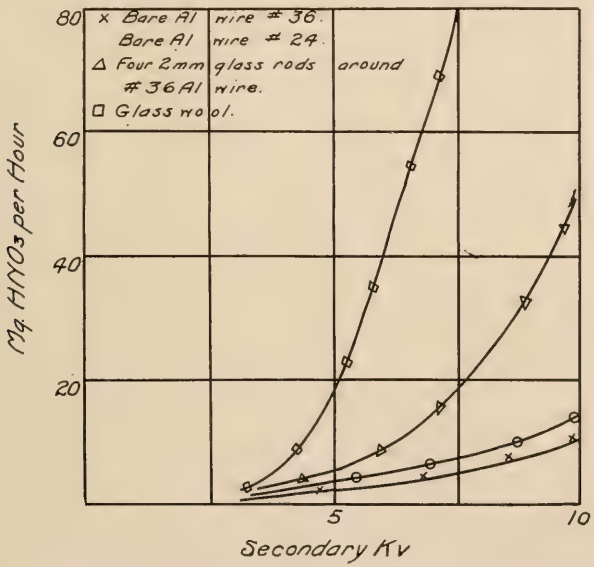

Fig. 7. Nitric acid formation with and without fragments of dielectric material in contact with the discharge.

the intensity of the discharge the amount of nitrogen activated increases. The ozone or ozone forming activated oxygen is used up to combine with this nitrogen and then to further oxidize to nitrogen pentoxide. Incidentally, with the increase in the intensity there is more local heating and catalytic decomposition of ozone. These sometimes have, with rising voltage, a periodic increasing and decreasing in which the opposite slopes of the ozone and nitric acid curves are the noteworthy feature. Blue flint has been found to be the best material for the production of ozone except at very high voltages when no dielectric material is desirable. Glass wool is much more effective than glass rods for the oxidation of nitrogen.

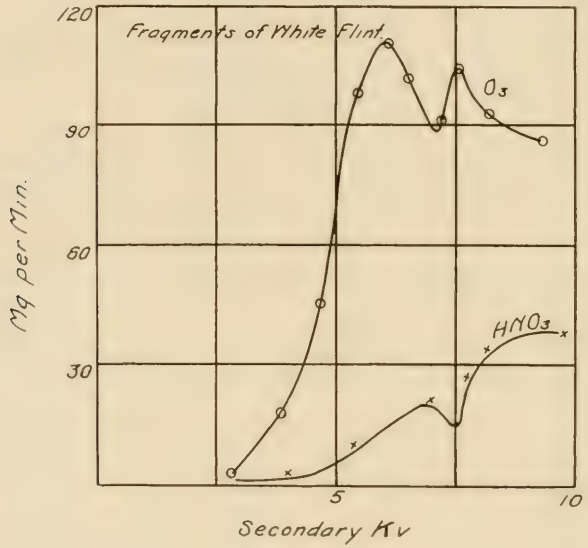

Fig. 8. Ozone and nitric acid formation in contact with fragments of white flint. Note the depressing action of the higher yields of nitric acid on ozone formation.

The curves for the decomposition of carbon monoxide are remarkably similar in shape to the curves for nitric acid production and so have not been given. The color of the discharge in carbon monoxide is worthy of remark. It is a pale light green, sometimes with a bluish tinge. With increase in air content it shifts over into the characteristic purple of resonant nitrogen. A tube which had been subject to discharge for some time was suspected to have carbon deposited on the fibers of the dielectric, glass wool. On letting in air and continuing the discharge some beautiful scintillations were observed. Little threads of fire would creep along the fibers and branch out to connecting fibers in a spectacular fashion. The notable differences in the results with different dielectric materials are due to catalytic action at the surfaces.

A FURTHER STUDY OF PRESSURE REVERSALS IN THE CORONA DISCHARGE.

F. O. Anderegg, Purdue University.

Last year K. B. McEachron presented a paper before this Academy, entitled, "Some Characteristics of a Siemens Ozonizer,"[1] in which a number of experiments with a corona discharge in stagnant air were described. Some very peculiar results were obtained which are not well understood. Further work seemed desirable and an account is given here of some experiments which have been made under somewhat dif-

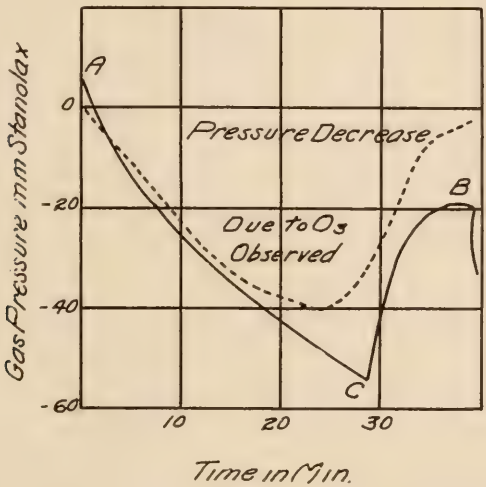

Fig. 1. There is usually an initial jump in the pressure on turning on the discharge due to the ionization pressure (Kunz). At C there is a reversal in pressure which is rather abrupt. When the current is turned off at B there is a sudden decrease in pressure due to the removal of the forces which produce the ionization pressure.

ferent experimental conditions. New facts are added to our knowledge of reversals and the foundation is being laid for an adequate explanation of these peculiar effects. It seems almost certain that the effects are catalytic in nature but the mechanism needs further elucidation.

Experimental: A No. 36 aluminum wire was placed at the axis of a Liebig condenser and was surrounded by four glass rods each two mm. in diameter. From the dielectric constant of the glass it is possible to calculate their dielectric effect on the discharge (Cf. preceding article). Air, dried and freed from carbon dioxide, was enclosed within the tube and the discharge was allowed to pass under definite conditions. The method of making analysis of the gases for ozone and oxides of nitrogen has been described.[2] A small transformer was used to step

[1] McEachron. Proc. Ind. Acad. Sci. 1921, p. 171.

[2] Anderegg. Proc. Ind. Acad. Sci. 1921, p. 159.

up 110 V. alternating current. The voltage was taken from the primary voltmeter reading and the transformer ratio. The gas pressure in the tube was measured by means of a manometer filled with "stanolax", a heavy paraffin oil with a density of 0.857. Some of the results obtained are given in figure 1. It is to be noted that there is a critical voltage above which there is no pressure decrease under the given conditions. At the lower voltages the first part of the decrease in pressure, when allowance is made for the ionization pressure[3] is exactly caused by the ozone formed as is shown in figure 2. Towards the re-

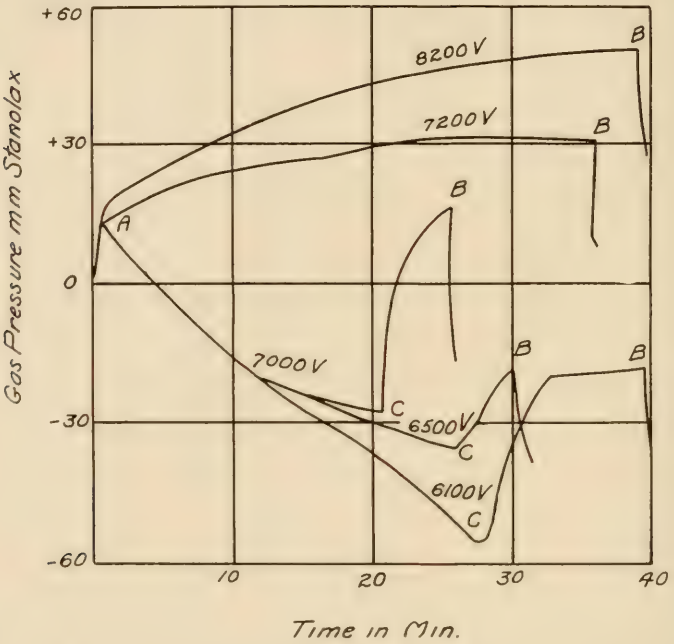

Fig. 2. A series of runs over varying length of discharge time was made at about 6100 volts.

versal point there is an accumulation of oxides of nitrogen which prevent the further formation of much ozone. This part checks McEachron's results.

Discussion. In the corona discharge ozone is the chief product formed at first, provided the intensity of the discharge and the temperature are not too great. A little nitrogen is oxidized, which gradually accumulates with time, and not only reduces the ozone concentration, but prevents further ozone formation. There are two possibilities, one is catalytic decomposition of the ozone molecules in the gas space by oxides of nitrogen; another is the adsorption of the oxides of nitrogen, (these may possibly be very heavy molecules), on the walls

[3] Kunz. Phys. Rev. 8, 285 (1916); 10, 483 (1917); 19, 165, 244, 390 (1922).

of the tube where the ozone may be catalytically decomposed. In addition the accumulation of oxides of nitrogen on the walls will change the nature of the surface and therefore the nature of the discharge is apt to be altered. The discharge tends to be concentrated into a few brushes in which the more intense activation allows less and less ozone to exist. Finally, when the whole wall is all covered a further change in the discharge occurs. The adsorbed molecules are more or less driven off and decomposed, explaining the pressure increase. There is, doubtless, a very complicated state of affairs. This hypothesis gives an explanation of the observed facts. It is now being further tested experimentally.

IMPROVED DESIGNS OF SOUND CONDENSERS.

ARTHUR L. FOLEY, Indiana University.

The writer has shown in former papers that a number of the generally accepted theories in regard to the passage of sound through tubes[1] and the action of horns[2] are not tenable. The theory that when a horn is used as a sound "condenser" all or even the greater part of the energy entering the large end is condensed at the small end is far from the truth. Sound waves do not pass through a horn, like shot or water poured into a funnel. The energy condensed at the small end of a conical or flared horn is not even approximately equal to that enter-

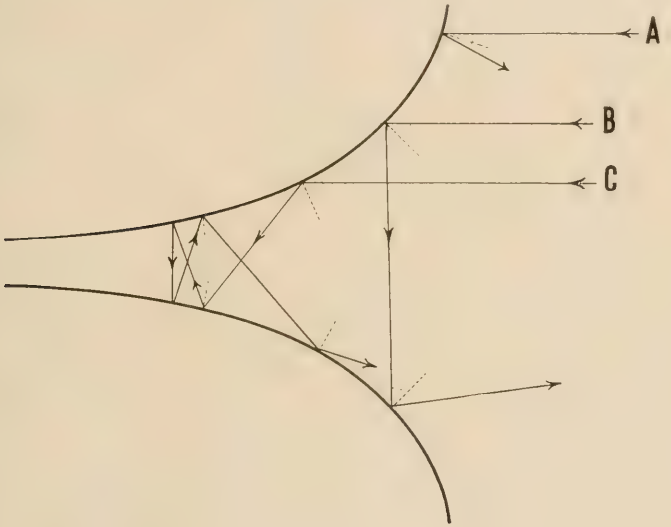

Fig. 1. Cross section of flared horn, showing how wave energy is reflected backward and out of the large end.

ing the large end. If the horn is one of large angle, the condensed energy is usually but a small fraction of the entering energy. The major part of the entering energy is lost by reflection; it backs out of the horn at the end it entered.

Owing to the fact that sound waves are long, compared to light waves, one can not—using sound reflecting surfaces of usual size, expect close agreement between optical and acoustical phenomena. Sound diffraction is a most disturbing factor. However, there is no reason why Huygen's theory should not be applied to determine the direction

[1] The Speed of Sound Pulses in Pipes. Phys. Rev., N.S., Vol. XIV., No. 2, Aug., 1919.

The Velocity of Sound Waves in Tubes. Proc. Ind. Acad. Sci., 1919.

[2] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phys. Rev., S.S., Vol. XX, No. 6, Dec., 1922.

"Proc. 38th Meeting, 1922 (1923)."

of the main portion of a reflected sound wave. For this portion of wave the law that the angle of incidence equals the angle of reflection is as true as it is in the case of light. The writer has proved this statement in the case of sound pulses from electric sparks, by photographing such waves in various stages of reflection from surfaces of several different shapes.

Let us apply the law to the case of a plane sound wave entering the large end of a flared horn, as in figure 1. The portion of the wave which is lettered A is reflected back and out at the end it entered, after but a single reflection. The portion lettered B backs out after two reflections, while C does so after six reflections. Reference to the photographs published in the author's papers referred to above, shows clearly and conclusively that this is exactly what happens. The data therein

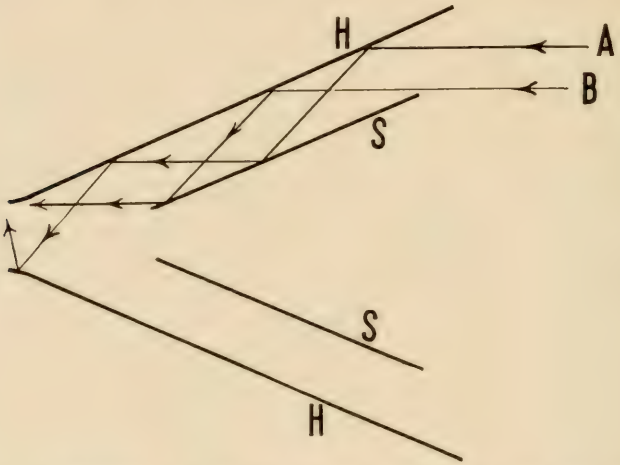

Fig. 2. Cross section of a multiple conical horn, showing how wave energy may be reflected to the small end of the horn, resulting in increased amplification.

published shows that a horn of wide angle "condenses" very little more energy than one of small angle.

Suppose now that we take an ordinary conical horn H, shown in cross section in figure 2, and place within it and coaxial with it a similar but smaller horn S. Then the portion of a sound wave A, instead of backing out of the horn after one or two reflections, is reflected first from the inner surface of the outer horn H, then from the outer surface of the inner horn S, then again from the inner surface of H, thence to the small end of the horn. Likewise, the portion of the wave lettered B, and therefore all portions of the wave between A and B.

To take care of the energy falling on the *inner* surface of the horn S, a third and still smaller horn may be placed within S, and so on. Thus, by using a number of nested, and spaced horns the energy condensed at the small end is materially increased over anything possible with a single horn.

The shape of the external horn is not necessarily conical, nor is it entirely arbitrary. It is determined by the use to which the horn is to be put, to its length, aperture, and small end diameter, to the distance to the sound source, to the extent it is desired to make use of the horn as a sound resonator, and to the pitch and quality of the sound to be amplified or condensed.

Figure 2 shows both horns, H and S of the same shape. This is not always the most efficient design. The shape of the outer horn having been decided upon, the inner horns are so shaped as to condense the maximum amount of energy at the small end. They are supported by radial strips of sheet metal placed with the plane of the strips parallel with the common axis of the horns, in order to give minimum interference to the passage of sound waves through the system.

The writer is still experimenting with multiple horns of different designs, in order to determine the one having the maximum efficiency. An account of this work, with data, will be published later.

LOCOMOTIVE WHISTLE EXPERIMENTS.

Arthur L. Foley, Indiana University.

A study of the amount of steam, and consequently the amount of coal, required to blow an ordinary locomotive whistle, the probable average time per day the whistle is blown, and the total number of locomotives in use, convinces me that we "pay dearly for the whistle". Is it not possible to reduce the cost and the coal waste?

In the first place, it would seem that the position of the whistle is bad. It is almost always behind the smoke stack, and frequently behind or at the side of the steam dome, bell or sand box. Sound shadows are not pronounced like light shadows. Nevertheless sound shadows actually exist. The intensity of the sound along the track in front of a locomotive is certainly somewhat lessened by placing the whistle behind the smoke stack or other objects. But it is much further reduced by the hot gases coming from the smoke stack, which act like a dispersing cylindrical lens. Moreover, the currents of hot air about the walls of the smoke stack and rising from the boiler are both absorbing and dissipating for sound energy. That such conditions are undesirable can not be questioned. The question concerns the magnitude of their effect. Is the reduction in the intensity of the sound along the track sufficient to warrant placing the whistle in front of the locomotive smoke stack, as is the case with the headlight?

A second question. Can one devise a sound reflector that will increase the sound intensity along the track where it is needed and decrease it in other directions where it is not only not needed, but is usually a nuisance?

It has been argued that sound waves are relatively so long that a reflector of ordinary size would have little or no effect. Certainly we should not expect results anything comparable to what we have in

the case of the headlight reflector. But it is wrong to expect nothing. Whenever one places his hand to his ear in order to hear better, he makes use of a reflector many times smaller than the whistle reflector would be, yet the hand gives results. So does a megaphone.

In order to settle the question raised above the writer arranged to measure the intensity of sound in various directions and at various distances from a locomotive blowing a whistle. The Monon Railroad Company kindly placed at my disposal one of their mogul engines, with engineer, fireman, and men to operate the turn table on which the locomotive stood. Instead of moving my point of observation to measure the sound intensity in various directions, I set up my apparatus at the side of the track at the desired distance from the locomotive, and measured the sound intensity as the locomotive was turned on the table. This method has many advantages over one in which the observer changes his points of observation, one of which is that the sound is always traveling over the same surface contour in the same direction with respect to wind, etc. The writer expected to make measurements —first without a reflector, to determine the effect of the position of the whistle, then with a reflector to determine its efficiency. The experiments begun late in the fall, were interrupted by a notice from a family living near the railroad roundhouse that, owing to sickness, the noise would not be tolerated. I hope to continue and complete the experiments in the spring. I shall defer publishing data until the experiment has been completed.

I wish to take this opportunity to thank Mr. H. R. Kurrie, President of the Monon Railroad Company, Mr. J. T. Strubel, master mechanic, and Mr. J. Little, roundhouse foreman, for their courtesy and co-operation.

A METHOD OF MEASURING THE AMPLIFICATION OF TWO OR MORE STAGE AMPLIFIERS.

R. R. RAMSEY, Indiana University.

The method here explained is an adaptation of the potentiometer method of measuring the amplification constant of an electron tube.

In figure 1 (Audio Amplifier) the negative terminal of the filament is connected to the middle point, b, of a potentiometer made of two ordinary resistance boxes. This negative terminal may be connected to the earth also. An alternating E.M.F., generated by a buzzer working through a telephone induction coil, is connected to the terminals, c, c,

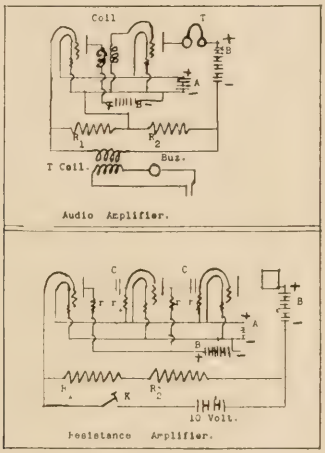

Fig. 1. Diagram of audio and resistance amplifiers.

of the potentiometer. The point, a, is connected to the grid of the first tube and the point, c, is connected through a suitable B battery and telephone to the plate of the last tube.

The tubes are carefully connected with audio frequency coils. The coil must be so connected that when the potential of the grid of tube No. 1 is made positive the potential of the second and of all other tubes is positive. When the grid potential of the first tube is made positive the plate current of all tubes must increase. A second B battery must be used for the plate potential of all tubes except the last.

When the potential of the point a is positive the current runs from a to c through b. The potential of c will be negative, since the potential of b is zero.

If the potential of the grid of tube No. 1 is raised, the current in the plate circuit of the last tube is increased unless the plate potential is decreased. When the plate potential is diminished enough to keep the plate current constant there will be a minimum sound or no sound at all in the telephone.

"Proc. 38th Meeting, 1922 (1923)."

If the resistance R_1 is set at some convenient value, 10 ohms, say, and R_2 is adjusted to minimum sound, then the ratio of R_2 to R_1 is the amplification constant of the amplifier.

$A=R_2/R_1$=Change of plate potential divided by the change of grid potential. If the amplification constant of the tubes has been determined then the amplification constant of the audio coil can be determined. $A=a_1C_1a_2C_2a_3—a_n$.

Where a_1, a_2,—a_n is the amplification constant of the various tubes, and C_1, C_2—is the amplification constant of first, second, etc., coils.

Best results are obtained with two tubes and one coil. The plate potential must be such as to let the tubes operate on a point near the middle of the plate current, grid potential curve. C batteries of suitable value may be inserted in the grid circuits of the tubes, if necessary.

In a resistance amplifier (fig. 1, resistance amplifier) an uneven number of tubes must be used. If the grid of the first tube is increased the plate current increases and the potential of the plate diminishes, causing the potential of the grid of the second tube to diminsh and the plate current of the second tube to diminish. This will cause the potential of the second plate to increase and the grid of the third tube will increase and the current in the plate circuit of tube three will tend to increase.

The resistances in the potentiometer can be adjusted until there is minimum sound as in the first case. A mil ammeter can be inserted in place of the telephone and a battery of a few volts can be placed around a c. A key, K, in the battery circuit is opened and closed and the resistances adjusted until there is no change of deflection.

In this resistance amplifier the actual amplification will be less than the product of the amplification constants of the three tubes. If the resistance, r, is four times the resistance of the tube, then the amplification is four-fifths that of the tube alone. The potential of the B battery must be large. If the tube is to work with 40 volts potential on the plate then the battery must be 200 volts if r is four times the resistance of the tube.

A METHOD OF SECURING ACCURATE HIGH FREQUENCY STANDARD.

R. R. RAMSEY, Indiana University.

In the Trans-Atlantic radio stations of the Radio Corporation of America, Alexanderson alternators are used to generate the high frequency current. The frequency of these alternators depends upon the speed of the rotor. This is regulated by automatic devices so the variation is less than two-tenths of a per cent. A recording device registers the speed every minute.

A radio receiving circuit containing an oscillating three electrode tube can be tuned until the difference of the frequency of the tube and that of the alternator is some fixed value, for example, the frequency of a standard tuning fork. Then from the frequency of the fork and the speed of the alternator the frequency of the tube or local radio circuit can be obtained.

These Trans-Atlantic stations operate practically continuously. So the high frequency standard is always available. By arranging in advance the operators of the stations will take special pains to hold the speed constant and will send you the exact speed of the machine covering any particular period.

"Proc. 38th Meeting, 1922 (1923)."

AN INVESTIGATION OF THE FOLEY TELEPHONE MOUTHPIECE.

JAMES E. BROCK, Sweetser, Indiana.

One of the chief results of Dr. A. L. Foley's photographic studies of sound pulses through horns is the discovery that the condensing power of flared horns is considerably less than what has been taught by physicists heretofore.[1] The heretofore accepted theory is that the condensing power of such horns is inversely proportional to the areas of cross-section of the ends.[2] Researches by Foley, Cloud, and others at Indiana University have shown conclusively that such is not always the case. In fact, it was found that in flared horns there seems to be an

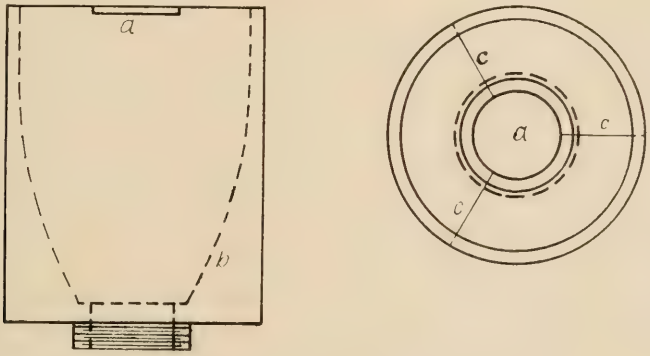

Fig. 1. Foley telephone mouthpiece.

actual "backing out" of some of the energy[3] which enters the wide mouth of the horn, instead of all passing through, as the old theory demands. It was also found that horns having a somewhat parabolic curvature as indicated in figure 1 seemed to have much greater condensing powers than those that are flared in the manner ordinarily found on telephone transmitters. The net result of all these studies was the Foley Telephone Mouthpiece shown in figure 1. As one would expect from the geometry of the parabola a marked advantage of this type of horn comes from the focusing effect of the curve. It was sensed that one very serious fault of the flared horn mouthpiece was the fact that all sound waves created in any instant did not arrive simultaneously at the diaphragm of the transmitter, due to the fact that some of them had to suffer reflections while others traveled directly in without impedence of any kind. This was overcome in the case of the Foley Telephone

[1] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phy. Rev., Dec., 1922.

[2] A. L. Kimball, College Physics. Revised Edition, pp. 196-197.

[3] *Ibid.* See 1.

Mouthpiece by suspending a small disc flatwise in the mouth of the horn as indicated in figure 1, *a*, so that all pulses striking the diaphragm would suffer one reflection, and therefore equal retardation. This improvement eliminates a large part of the buzzing and muffled tones common in telephones.

The arrangement of the apparatus used for taking the data in this report is indicated in figure 2, and is a modification of the "hook-up" employed by the Kellogg Switchboard and Supply Company in their common battery telephones.[4] A, A′ are telephone transmitters, shown in the diagram with the ordinary flared horn; R, R′ are adjustable resistances, R having a capacity of about 50,000 ohms and R′ about 10,000 ohms; L, L′ are induction coils (small telephone coils with cores); C is a

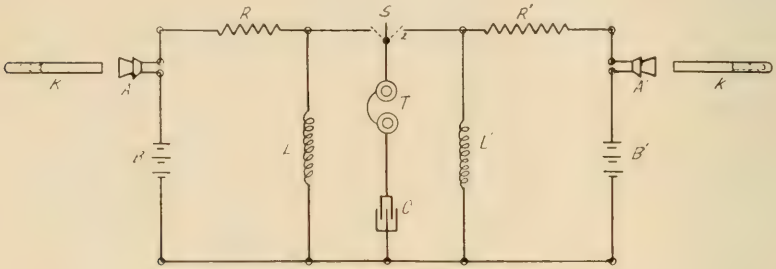

Fig. 2. Hook-up for the experiment.

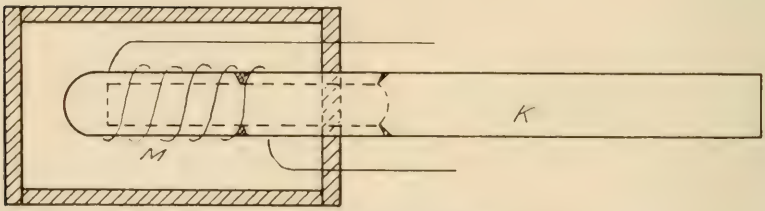

Fig. 3. Heating oven for Knipp Tube.

1/3 m. f. condenser; T a Baldwin mica-disc receiving set; B, B′ are 2 volt storage cells; and S is a double throw switch arranged so that either transmitter could be instantly thrown into the circuit.

In figure 3 are shown the details of the heating oven for the Knipp Singing Tube. M is a coil of three or four turns of No. 28 nichrome wire and was heated on the 110 volt circuit with about 5 amperes of current. The walls of the oven were made of asbestos sheeting, such as is ordinarily used to cover steam pipes, from which the hemp and sisal body had previously been burned so that it would not stain the glass tube. Knipp Tubes were chosen for the experiment because they came more nearly than any other sounding instrument to giving a point source of sound, while tests have shown that the tones[5] given off by

[4] "Principles of the Telephone," p. 99, by Jansky and Faber.

[5] New Standard of Sound Energy. C. T. Knipp. Phys. Rev., Feb., 1920. pp. 155-156.

them are almost pure. The tubes used in the experiments were so sensitive that it was only necessary to heat the wire to a dull cherry red temperature to make them sing in a smooth, loud tone. The especial advantage of the electric heating even over any open flame was that it gave an even temperature that did not seem to injure the tube by congealing the glass.

As would be expected, it was found that a proper balancing of the capacity and inductances in the telephone circuits gave the best results. Two common telephone coils at L and L′ against a 1/3 m. f. capacity at C seemed to give the best results of any arrangements tried.

Considerable experimenting with different telephone "hook-ups" was done before it was finally decided that the arrangement in figure 2 would be best for our purpose. The theory for the arrangement is as follows: With switch S on contact point 1 the circuit for transmitter A is complete. Any steady currents passing through transmitter A will pass unimpeded through the inductance L, but intermittent or A. C. currents would suffer considerable impedence. The intermittent or A. C. currents set up by the transmitter diaphragm will, however, readily discharge through the condenser and the receiver set. By this arrangement no direct currents flowing in the circuits ever disturb the receiving set T, but practically the whole energy of the A. C. currents created by the vibrations of the transmitter diaphragm will discharge through the condenser. You will notice that both the circuits A and A′ are just alike.

In taking data, one of the transmitters, assume in this case A′, was used as a reference transmitter. The tube K′ was set singing and resistance was "plugged in" in R′ until the sound was just audible in the receivers T, S being set on contact point 2. With this adjustment made the switch S was set on contact point 1 and the tube K set to singing. Resistance was now "plugged in" in R until no difference could be noticed in the intensity of the tone when the switch S was rapidly thrown from point 1 to point 2. (The tubes K, K′ were of practically the same pitch and as nearly the same size as it was possible to make them.) No change was made in the resistance R′ for any set of readings after once adjusted for minimum audibility. The first reading on each horn studied was made with the mouth of tube K just flush with the end of the horn on the transmitter A. Readings were then taken as the tube was moved back to various distances from the mouth of the horn. By placing different types of horns on the transmitter comparisons could be made of the relative intensities of the tones transmitted at any distance. In this research comparisons were made for *no horn*, ordinary *flared horn*, and the Foley Telephone Mouthpiece. The observations were made in an especially arranged, sound-proof room; the walls, floor, and ceiling of which were covered with felt about one inch thick. Long strips of this same felt about one foot wide were also cut and hung edge-wise along the walls and ceiling to break up any reflections that might occur. The singing tubes K, K′ were set at opposite ends of the room, a distance of about twenty feet, and the receiving apparatus was moved out into the adjoining hall. Observa-

tions were made at night, for noise during the day interfered with the hearing of the extremely low tones. All the curves shown have been checked on at least three different evenings and I am certain that the slope and relative intensities at the different distances are as nearly correct as the conditions of the experiment and the apparatus would permit.

Data:

No horn		Flared horn		Parabolic horn		Parabolic horn with disc	
D	R	D	R	D	R	D	R
0.0	30700	0.0	18000	0.0	33000	.5	20000
.5	17000	.5	13000	.5	26000	1.0	23000
1.0	8000	1.5	6000	1.0	23000	2.0	14000
1.5	7000	2.5	5000	1.5	21000	3.5	10000
2.5	4000	3.5	4000	2.0	20000	5.5	7000
3.5	3000	5.5	1600	2.5	18400	8.0	3000
5.0	2900	7.5	600	3.0	14000	11.0	1000
7.0	1400	11.0	200	3.5	11000	14.0	400
10.0	1000	15.0	000	4.0	7000		
13.0	200			4.5	5000		
16.0	100			5.0	4400		
				7.0	3000		
				9.0	2000		
				11.0	1000		
				14.0	1000		
				19.0	800		
				23.0	400		

Above is the data for the four curves shown in figure 4. D is the distance from the mouth of the horn to the nearest end of the singing tube. R is the resistance "plugged in" in the test circuit A to reduce the tone to the same intensity as that in the reference circuit A′.

It is noticed there is a marked superiority in the Foley Telephone Mouthpiece (parabolic horn) as is shown by the curves 3 and 4 (fig. 4), and that this superiority holds especially at the ordinary speaking distances of from 5 cm. to 10 cm. It was necessary to plug in almost twice as much resistance in the circuit at 5 cm. to reduce the intensity of the parabolic horn to minimum audibility as for the *No horn*, and the ratio is about 5 to 1 for the flared horn. This increased efficiency is probably due in no small part to resonance[6] in the horn and is as marked for the speaking voice as for the pure tone of the singing tube. When the small disc was inserted in the mouth of the horn so that the focusing effect was a maximum the efficiency was considerably increased for 4 cm. to 9 cm. as is shown by curve 4. This curve exhibits a freakish tendency to rise upward until a distance of about one centimeter is reached when the slope reverses and it drops off in a smooth curve. This tendency of the curve to rise for a short distance was probably due to the shielding effect of the disc when the source is near to it. The

[6] D. C. Miller. The Science of Musical Sounds. pp. 156-159.

high sensitivity of the *no horn* curve at zero distance is undoubtedly due to the fact that the diaphragm of the transmitter was almost adjacent to the tube so that the total energy given off at the source was almost all absorbed by the vibrating disc. The rapid falling off of the curves shows vividly how the energy falls off with distance out from the horn.

The apparatus was also used to make some investigations of the sound pattern about the mouth of the singing tube for which it seemed

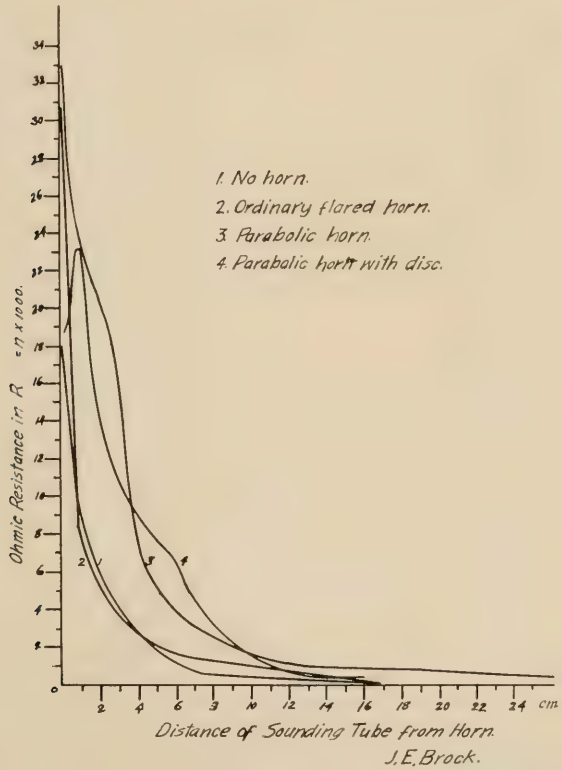
1. No horn.
2. Ordinary flared horn.
3. Parabolic horn.
4. Parabolic horn with disc.
Ohmic Resistance in Ω x 1000.
Distance of Sounding Tube from Horn.
J. E. Brock.

Fig. 4. Graph of curves showing superiority of the parabolic horn.

to be singularly well adapted. The energy given off by the singing tube seemed to be largely confined to a cone shaped region in front of the tube with the mouth of the tube at the apex. The boundaries of this sound cone seemed to be very sharply defined. It is hoped that in a short time enough data will have been secured so that more definite ideas may be formulated concerning the sound pattern of this cone.

In concluding I wish to express my thanks to Dr. A. L. Foley, of Indiana University, and Dr. C. T. Knipp, of the University of Illinois, for their kindly interest and many helpful suggestions offered during the progress of the experiments outlined in this research.

THE OCCURRENCE OF SECONDARY PARASITISM IN THE FROG.

GEORGE ZEBROWSKI, Purdue University.

In a series of experiments on the life histories of certain Anuran parasites, especially those of *Rana pipiens*, conducted under the direction of Dr. H. E. Enders, several cases of secondary parasitism have been observed, two of which are described in this article.

By secondary parasitism is meant the occurrence of parasites in forms which themselves lead an essentially parasitic existence. To the uninitiated the mention of a parasite often brings to mind a few common forms such as the louse, the flea, the tick, or perhaps a tapeworm. Unless one is actively engaged in the study of parasitology, it is difficult to appreciate the tremendous number of parasitic forms that may be found at one's very elbow. Indeed, it may be conservatively stated that every animal, during its lifetime, is a host to one or more species of parasites which are dependent upon it for their existence.

This statement is prompted by a small, moribund, leopard frog, which the writer recently dissected and which contained the following astonishing list of parasites:

FLATWORMS.

Pneumonoeces coloradensis, in lungs, 5
Loxogenes arcanum, encysted in musculature of stomach and intestine, 14
Clinostomes (sp.?), immature forms encysted generally, 137
Diplodiscus temperatus, in rectum, 5
Gorgoderina attenuata, in bladder, 3

ROUNDWORMS.

Angiostoma nigrovenosum, in lungs, 7
Strongylus auricularis (?), in intestine, 4
Small, immature, active, free-living nematodes, (species?), in body cavity, 17

PROTOZOA.

Opalina, and Nyctotherus, several hundred in intestine and rectum.

The infestation of parasitic forms by other parasites is a common phenomenon, and especially is this true in the case of Protozoa. Thus, the orders Flagellata, Gregarinida and Coccidiidea are replete with parasitic species that may be dependent upon other parasites, commonly insects, for their transfer to a final host. The Trypanosome of "sleeping-sickness" and *Plasmodium vivax*, the causative agent of malaria, are two of a number of well known examples which may be cited. It is true that secondary parasitism among the higher metazoa is more difficult to find, but this is probably due to lack of research, rather than to a lack of material. It is now definitely known that fleas are intermediate hosts for larval stages of certain tapeworms. We have also good reason to believe that other helminth forms can be transferred by insects in this way. Doubtless this list could be further augmented, but

"Proc. 38th Meeting, 1922 (1923)."

the examples already cited will suffice to show some of the parasite relationships that may be found. They indicate moreover, the economic value of studies in this field.

To the above list the writer would contribute a new form of parasite relationship, namely, the occurrence of Distome larvae in other immature parasites. The only analogous case of which we have any

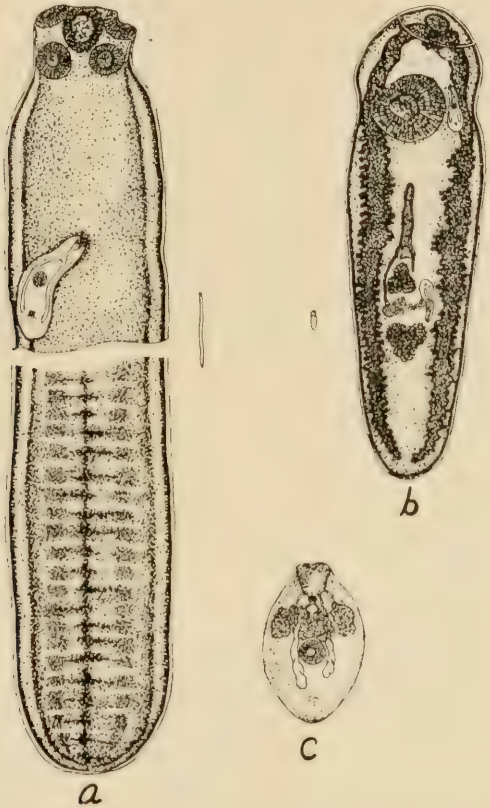

Fig. 1. a, Anterior and posterior ends of larval cestode, showing Distome larva parasite in anterior portion, x 12; b, immature *Clinostomum marginatum* parasitized by three larval Distomes, x 12; c, *Agamodistomum marcianae* (?), the larval Distome infesting the above parasites, x 25. The small figures indicate one-half natural size.

record is one reported by Cort[1] in which a Trematode was parasitized by Gordius larvae. In the accompanying figure are shown two parasitic forms in which secondary infestation was found. The first (fig. 1a) is an immature Cestode, one of seven specimens taken from the same liver. These were free-living rather than encysted forms and were woven in and out throughout the parenchyma of the liver. They were

[1] Cort, W. W. Gordius Larvae Parasitic In a Trematode. Jour. Parasit., 1:198-199. 1915.

teased out with the greatest difficulty, and when isolated, were glistening white in color, ranged in length from one to three inches, and possessed a well defined scolex with four suckers but no hooks. These Cestodes were also peculiar in having a cylindrical body. The available records of Anuran Cestodes list but three species from this country. These are, *Nematotaenia dispar* Goeze 1782, *Taenia pulchella* Leidy 1851, and *Cylindrotaenia americana* Jewell 1916. Jewell[2] considers the last two identical, and also questions the occurrence of *Nematotaenia dispar* in North America. If these contentions are valid then the Cestodes under discussion are either a new species or identical with *Cylindrotaenia americana*. They unquestionably belong to the Nematotaeniidae, even though from their immature condition the species could not be determined with certainty.

The second (fig. 1b) shows the larva of *Clinostomum marginatum*[3] taken from a subcutaneous cyst. These forms always occur encysted singly, and are very abundant, it being nothing unusual to find several dozen in a single frog. From personal observation it would appear that two species are concerned. The first is a relatively large form with a smooth cuticle, while the other is a smaller, more slender form, with a spiny cuticle. It may be that these are different stages in the development of the same species. A fair degree of dexterity is needed to separate these forms from their tough membranous sheaths without injury. However, when once liberated they are active and extensile to a degree. In conducting the experiments already outlined, three of these Clinostomes and one Cestode were found that showed infestation, presumably with the same species of parasite. The illustrations for the figure were prepared from specimens mounted *in toto*, and stained with equal parts of acid carmine and alum cochineal. Attempts to measure living material were unsuccessful as these animals changed their shape too rapidly to yield accurate results.

The parasite found infesting the above forms was a diminutive larval Distome shown in figue 1c. In this case the specimen was teased out of one of the Clinostomes already mentioned and this illustration, like the others, was drawn to scale from a prepared mount. Careful search elicited the presence of these parasites in practically every frog examined, while in some individuals literally hundreds were found. These forms were active, free-living, and migrated extensively throughout the tissues of the host. The easiest way to obtain them in number was to scrape the inverted skin of a frog in normal salt solution. In the fine residue thus obtained numerous Distome and other larval Trematodes could usually be found under the microscope. Living specimens showed a well defined forked digestive tract and an emulsified structure of the protoplasm. They were unusually active and extensile, changing their shape continually in the process of locomotion. They were also more slender than the drawing would indicate, as the mounted

[2] Jewell, Minna E. Cylindrotaenia americana nov. spec. From the Cricket Frog. Jour. Parasit., 2:181-191. 1916.

[3] Osborn, H. L. On the Distribution And Mode Of Occurrence in The United States And Canada Of Clinostomum Marginatum, A Trematode Parasite In Fish, Frogs And Birds. Biol. Bull. No. 5, Vol. XX, pp. 350-367. 1910.

specimen is much shrunken and fore-shortened. These forms occurred chiefly in the connective tissues of the host, but could be found generally throughout the body, as in the lungs, the digestive tract, the body cavity, and in the liver and spleen. In these last their presence was indicated by gray, granular, necrotic patches upon the surfaces. On several occasions these Distomes were observed in the web of a frog's foot, where they seemingly had no difficulty in making their way, moving rapidly across the field of the microscope.

The extent to which these Distomes are true parasites of the forms they infest is problematical. In all cases where this infestation occurred an excessive number of free-living Distomes were also found in the tissues of the frog. In neither the Cestode nor Clinostomes were these secondary parasites encysted, a fact which would suggest a fortuitous occurrence. It seems altogether probable that in their extensive migrations these small forms could accidentally force their way into other parasites, especially if the body substance of these offered less resistance than did the tissues of the primary host. These secondary parasites varied considerably in size, but were of the same general appearance. Because of their immature condition no exact identification is attempted. In their gross anatomy they agree closely with *Agamodistomum marcianae*,[4] a cercaria described by Cort as follows: "The ventral surface is completely covered with spines which are very thickly set over the anterior tip and somewhat scattered in the post-acetabular region. The margin of the acetabulum is armed with two or three rows of closely set spines pointing in, which are so placed that they add greatly to the gripping power of the sucker. The host in which *Agamodistomum marcianae* complete its development is not known. Also its structure at this stage gives little clue to the systematic position of the adult. The character of its cephalic glands and excretory system, however indicates that it has developed from a forked-tailed cercaria."

[4] Cort, W. W. The Excretory System Of Agamodistomum Marcianae (La Rue), The Agamodistome Stage Of A Forked-Tailed Cercaria. Jour. Parasit., 4 130-134. 3 figs. 1918.

NOTES ON THE MAMMALS OF THE DUNE REGION OF PORTER COUNTY, INDIANA.

MARCUS WARD LYON, JR., South Bend.

The following notes on the mammals of the dune region of Porter County are based primarily on a small collection which was made during a brief camping trip into the dunes during the autumn of 1922. They are supplemented by observations on mammals seen but not captured during that trip and numerous Sunday excursions and on reports of apparently good authority. So far as I am aware there are no previously published comprehensive records of the mammals of Porter County. These notes contain little of novelty, but it seems desirable to publish them because owing to the invasion of the region by week-end visitors, the erection of permanent cottages along the lake front, and more or less extensive forest fires it is not unlikely that the biological aspects of this very interesting region will be rapidly altered. Many animals and plants now common in the region are probably destined to disappear as completely as the once common Virginia deer.

Our tent was pitched in a sheltered spot a few yards back from the lake front and about 50 or 60 feet above its level, north of Mineral Springs station of the Chicago, Lake Shore and South Bend Railway. Traps were set in the neighborhood of our camp and westward to opposite Oak Hill station.

Acknowledgement is here made of the valuable assistance of my wife, Dr. Martha Brewer Lyon of South Bend, not only for help in placing traps and looking for mammals but also for acting as chef, etc. while I skinned specimens. Special thanks are also due to Mr. H. W. Leman of Chicago, for the privilege of camping on his property, and to Mr. Gerrit S. Miller, Jr., of the United States National Museum for assistance in the identification of specimens. The specimens collected have all been deposited in the National Museum.

As is well known the sand dunes at the southern end of Lake Michigan are not barren tracts of sand. They present a variety of physiographic features and characteristic associations of plants, if not of mammals. In a general way these may be briefly described as follows.*

The beach proper: This is the area between the calm low water level of the lake and the rough high water level. It is practically devoid of permanent vegetation. While perhaps most of the beach area is dependent upon the size of the breakers formed after every heavy northerly wind on the lake, some of it is evidently due to actual changes in the water level. Northern winds seem to blow the water shoreward as well as to throw it into large waves, while an off shore wind blows it away again. Differences in barometric pressure over different areas of the lake may also have an effect in altering the water level. Even

* For a detailed description of the various associations in the region see *A Naturalist in the Great Lakes Region* by Elliott Rowland Downing, 1922, and for topographic features *Rand McNally's Map of Indiana Dunes* by P. S. Goodman [1920].

"Proc. 38th Meeting, 1922 (1923)."

on essentially calm days the water does not always appear at the same level.

The fore dune region: The fore dunes are low wind-blown piles of soft sand immediately back of the high water mark of the beach and parallel with the water line. Vegetation on them is not abundant in kind or in number, but is not inconspicuous. The most characteristic plants are sand reed-grass, *Calamovilfa longifolia;* maram grass, *Ammophila arenaria;* and sand cherry, *Prunus pumila.* This area gradually blends in with the higher wooded dunes, bare faces of which are characterized by the same association of plants. Around the margins of blowouts (wind-worn cuts into the larger, wooded and more mature dunes) an association of plants similar to those of the fore dunes occurs mingled with plants of the first portions of the wooded dunes. The only mammals found in the fore dune region were the Baird deer mouse, *Peromyscus maniculatus bairdii* and a few house mice, *Mus musculus.* As the same species of deer mouse was found in an interdunal meadow it can not be considered a characteristic inhabitant of the fore dunes.

Wooded dunes: These are the characteristic dunes of the region and occupy the greatest area. They are immediately back of the fore dunes and range in height from 50 to 150 feet. They are covered with permanent vegetation. According to the abundance of certain plants on them and to their proximity to the lake the wooded dunes may be roughly divided into a lakeward portion characterized by an abundance of such plants as white pine, *Pinus strobus;* jack pine, *Pinus banksiana;* common juniper, *Juniperus communis;* red cedar, *Juniperus virginiana;* red osier dogwood, *Cornus stolonifera;* aromatic sumac, *Rhus canadensis;* fox grape, *Vitis vulpina;* basswood, *Tilia americana;* and a considerable number of white and black oaks, *Quercus alba* and *Q. velutina;* and into a landward portion where the oaks predominate and where there is usually a dense growth of blueberry, *Vaccinium pennsylvanicum.* The two portions are not sharply defined but the vegetation has a tendency to be disposed as mentioned. The lakeward portion of these dunes is quite uniform in height, ranging about 50 or 60 feet, and the vegetation of their north faces blends in with that of the fore dunes. The landward portions vary considerably in height and may be only low hills or ridges or rise to high hills of 150 feet. The wooded dunes are often broken into by blowouts and their landward slopes are often being covered by advancing sand. The common deer mouse, *Peromyscus leucopus noveboracensis* was very abundant in the wooded dunes.

Interdunal meadows and ponds: These are open treeless stretches between the wooded dunes and toward the landward side. They may be permanent meadows or permanent shallow ponds, or meadows which early in the season were shallow ponds. Around the edges of the permanent or temporary ponds there is always more or less meadow. These meadows are covered with a variety of annual and perennial herbaceous plants varying considerably in different meadows and drying ponds. Some of the meadows are quite damp and may contain much sphagnum and masses of such plants as cassandra, *Chamaedaphne calyculata,* chain fern, *Woodwardia virginica,* and sundew, *Drosera intermedia.*

About the edges of such meadows and ponds the sour gum, *Nyssa sylvatica* is found quite characteristically. Although such places appear to be quite ideal for many species of mammals, yet comparatively few runways or other signs of mammals were found in them. The species taken were the common deer mouse, *Peromyscus leucopus noveboracensis;* on one occasion, the Baird deer mouse, *P. maniculatus bairdii;* prairie and pine voles, *Microtus ochrogaster* and *Pitymys pinetorum scalopsoides,* and the short-tailed shrew, *Blarina brevicauda talpoides.*

Subdunal swamp or marsh: Between the tracks of the Chicago, Lake Shore and South Bend Railway and the dunes proper is an extensive area of low ground, almost as low as the level of Lake Michigan. At Mineral Springs station the track is said to be 13 feet above the lake level and the track is higher than the swamp. Part of this low ground drains into the lake at Waverly Beach by Dune Creek. Toward Michigan City much of this low ground is being cultivated and from most of the other treeless portions much hay is cut. Most of the subdunal swamp or meadow is treeless, but near the dunes in many places it is timbered with such trees as tamarack, *Larix laricina;* white pine, *Pinus strobus;* yellow birch, *Betula lutea;* occasionally, paper birch, *B. papyrifera;* red maple, *Acer rubrum;* elm, *Ulmus americana;* speckled alder, *Alnus incana;* and tupelo, *Nyssa sylvatica.* A conspicuous shrub in this area is the poison sumac, *Toxicodendron vernix.* Opposite Mineral Springs this wooded portion is usually termed the tamarack swamp although tamaracks are by no means the most common trees. Farther west white pines predominate, in places the floor being almost solid with their needles. Parts of this subdunal swamp are very boggy, containing such vegetation as pitcher plants, *Sarracenia purpurea;* cranberry, *Oxycoccus macrocarpus,* etc. In many places it is comparatively easy to sink to considerable depth in the more boggy portions. It is in such places if they should ever be explored or drainage ditches cut into them that one might expect to find remains of large mammals, elk, deer, bison which had become mired there years ago when such species were common in Indiana. In this subdunal swamp traps were placed in various sections excepting in the extremely boggy areas. The deer mouse, *Peromyscus leucopus noveboracensis,* was the common mammal. In the open portions of the marsh rattle-snakes, *Sistrurus catenatus* are frequently taken, especially during haying.

Dune Creek: This is a small sluggish stream draining part of the subdunal swamp. It starts in the Furnessville region and flowing slowly westward and northward empties into Lake Michigan just west of Waverly Beach. Most of its course is through swampy woods. Owing to lack of time no trapping was done along its course.

Mammals Collected in the Dune Region of Porter County or Mammals Observed in the Region.

Opossum (*Didelphis virginiana* Kerr): A few years ago near Dune Park Dr. and Mrs. W. D. Richardson found the dead body of a mature opossum and on another occasion found a half-grown young.

Prairie mole (*Scalopus aquaticus machrinus* Rafinesque): Residents

state that moles are not uncommon in the region, but they have escaped my personal observation. Wood (6) reports moles as very common on the dunes of Berrien County, Michigan. Runways such as made by moles are very common in the wooded dunes and I have even seen one such runway in the open sand at the top of a blowout. Traps set in these runways yielded many deer mice, occasionally prairie and pine voles, but never moles. It is well known that pine voles make runways essentially like those of moles and the evidence points to the vole as a more frequent maker of such runways in the wooded dunes than the mole.

Short-tailed shrew (*Blarina brevicauda talpoides* Gapper): Five specimens secured, a pair taken in traps in runways in sphagnum and cranberry at edge of an interdunal pond, one in a white pine swamp, and two in the treeless portion of the subdunal swamp. None were taken in the wooded dune region. This shrew did not appear to be common. Very rarely were any of the numerous collected deer mice ever molested in a manner suggestive of the usual depredations of short-tailed shrews. Traps were usually baited with bacon as a special inducement to shrews. Of the two taken in the sphagnum and cranberry, one was captured on checking up the trap line backwards after the night's catch had been taken out thus showing these shrews to be active by day and to be little frightened by persons working around their habitat. Measurements of the two males: total length 122, 103; tail 28, 21; hind foot 17.5, 14 mm. Of the three females: 112, 118, 105; 22, 28, 21; and 15, 17, 15.5 mm.

Red bat (*Nycteris borealis* Mueller): One afternoon in mid-summer I saw a curious looking object in some blackberry bushes. Almost as soon as I recognized it to be a female red bat it flew away. Bats are frequently seen on summer evenings and probably represent most of the species of bats recorded for the state by Hahn (4). The red bat is the only one seen sufficiently close to admit of identification. No specimens were secured.

Timber wolf (*Canis lycaon* Schreber): Timber wolves have probably been extinct in the dune region for some years. Residents state that wolves have been seen recently and if such is the case the animals are most likely the prairie wolf or coyote. Dice (2) records timber wolves as having been taken at Lakeside, Berrien County, Michigan, about 1909 and says that in 1911 four were killed southwest of Three Oaks, Michigan, just over the Indiana line, scarcely 20 miles away. Among some deer bones picked up in a blowout was a considerable portion of the left ramus of a member of the genus *Canis*. The carnassial is the only complete tooth in it. It measures (crown) 25 x 10 mm., height of main cusp 13 mm. The length of premolar and molar series of teeth (alveoli) is 83 mm. Mr. Gerrit S. Miller, Jr., says the carnassial "is below maximum for dog and therefore not diagnostic of wolf, though its size is rather great".

Prairie wolf or coyote (*Canis latrans* Say): Probably the animal referred to by residents when they say that wolves still inhabit or have lately been seen in the dune region. The species is not recorded by

Dice nor by Wood as among the mammals of Berrien County, Michigan, though the latter author (6) refers to its occurrence in Washtenaw County, Michigan, as late as 1910. Hahn (4) records it from Jasper and Laporte counties, Indiana, as late as 1903 and 1906. Newspaper accounts in October, 1922, state the presence of wolves, probably this species, in swamps near Leesburg, Kosciusko County. No fragments of coyotes or first hand evidence of their present occurrence in Porter County were obtained.

Red fox (*Vulpes fulva* Desmarest): This animal is apparently not rare in the dunes though not very frequently seen. Residents state that a small number are obtained each season for their fur. One was seen by my wife October 1, 1922. When we camped in Big Blowout in 1921, the tracks of what were apparently those of a fox were found on the slope of the blowout within several yards of our tent and in a comparatively straight line along the fore dune region for about half a mile. During the past summer, not far west of Michigan City, we found a large burrow in a hillside. It was much too large for a woodchuck's burrow and although no identifiable tracks were found about it, we believed it to be a fox den.

Raccoon (*Procyon lotor* Linnaeus): Residents state that a few "coons" are taken each season for their fur. I have no personal knowledge of the animal and I have never been fortunate enough to find foot prints that might have been made by it.

Weasel (*Mustela noveboracensis* Emmons): These animals are fairly common in the region, though I have never seen any. Mr. A. E. Didelot who has trapped about 200 specimens of weasels in the past three winters in the region of the dunes and near Chesterton, says that only two of that number were in white pelage. In Washtenaw County, Michigan, Wood (5) says only about 75 per cent of the weasels change to the white coat in winter. The percentage of those changing in northern Indiana appears to be much smaller.

Mink (*Mustela vison* Schreber): A number of minks are said to be trapped each season in the region. One dead specimen was collected on the bottom of a dried interdunal pond in a spot which had been covered with water two weeks before. The body gave the impression of not having been dead for more than a week or ten days.

Eastern skunk (*Mephitis nigra* Peale and Beauvois): Skunks are fairly common in the region and a number are taken each season for fur. By November 30, 1922, R. W. Sabinske had taken seven. He gave me two carcasses that he had not yet thrown away. They were covered with an enormously thick layer of fat. Their stomachs contained unidentifiable ground up material and a few small roundworms. His skins were all turned inside out, but he said they ranged in color from solid black except for a white patch on head to a specimen in which white predominated. There seems to have been some doubt as to the identity of the skunk in the dunes. Dice (2) uses *Mephitis nigra* for the animal of Berrien County, Michigan. Hahn (4) thinks the eastern skunk is one commonly found in the state, but in speaking of the Illinois skunk, *Mephitis mesomelas avia*, he says "It is very probable that this is the

species inhabiting all the northern part of the state". According to Cory (1) the region under consideration is in the area of intergradation of *Mephitis mesomelas avia* with *M. m. putida*. A. H. Howell of the Biological Survey has identified the two skulls given me as *Mephitis nigra*.

Northern deer mouse (*Peromyscus leucopus noveboracensis* Fischer): This deer mouse is the commonest mammal in the region. It was found in every situation except in the low dunes along the lake front where it appears to be replaced by the Baird deer mouse. The percentage of traps holding deer mice ranged from 10 to 40 a night except when the traps were placed in the fore dunes. Of the three baits employed, rolled oats, peanut butter, and bacon, the latter seemed to be the most effective. Several were taken in larger traps baited with apple and set for squirrels and chipmunks. They were quite common about our tent and helped themselves to exposed food. In addition to these taken opposite Mineral Springs, one of this species was taken in a wooded dune opposite Furnessville in 1921.

Most of the adult males were in a rather bright yellowish pelage although three or four had a short-haired coat of a sort of house mouse gray. In the case of the females about half were in a bright and yellowish pelage while the rest were in a short-haired house mouse gray coat. Only three young specimens in a "blue" pelage were saved. Two of these show an incoming yellowish coat on the sides.

Three stages of development are represented among the specimens collected, breeding adults, animals which have reached adult size and coloration but not yet breeding, and young specimens in the "blue" coat. In addition to these very immature young were noted. Of 18 mature females all were apparently nursing young, none being pregnant. The impression was gained that reproduction was carried on at regular intervals and simultaneously by nearly all the mice. On the spot where our tent was placed another party had previously camped leaving much food around and many pasteboard boxes. On our arrival, there was noticed in one of these boxes a Peromyscus nest, made of torn bits of paper after the manner of house mice. It contained several young covered with hair but unable to walk. On examining the nest a few hours later it was found the young had been carried away. As the previous occupants of the site had left Sept. 4 and we had come there Sept. 26, the mice had evidently built the nest and reared young of small size in the course of three weeks. The mammae are pectoral 1/1, inguinal 2/2=6.

In subterranean runways in which traps were placed for pine voles, deer mice were so often taken as to make one wonder if some of these runways may not have been made by them. In some of the interdunal meadows which had been quite wet or even covered with water earlier in the season were numerous holes apparently the work of crayfish though only rarely was anything suggesting a "chimney" seen. Traps set about these holes frequently yielded northern deer mice, some being caught in such a manner as to indicate that the animal had been in the burrow at which the trap was placed. Once a crayfish was caught in a trap placed at these burrows. W. D. Richardson states that deer mice frequently enter his cottage and have the same activities as house mice in cities.

The activities of these mice at night could be well inferred from their footprints in the sand the following morning providing the night had been still. Such footprints were well observed about our tent, and about the fox grapes, red osier dogwood, and grasses, plants growing out of clear sand. The usual mode of locomotion appeared to be a jump using all four feet at once. The tail appeared to have been carried in the air as no marks of it were left in the sand. The longest jumps were from 10 to 12 inches, but usually they were much shorter being but little more than the length of the animal. Only rarely did one find foot impressions showing that the animals had been walking and sometimes, in such cases, what appeared to be tail marks could be seen.

Extreme and average measurements of ten adult males: total length 180, 172, 160; tail 82, 79, 75; hind foot 22, 21, 20 mm. Of ten adult females: 187, 176, 172; 88, 80.5, 75; 21.5, 20.5, 20 mm.

Between five and ten per cent of these mice captured were infested in the inguinal region with a large fly larva, perhaps *Cuterebra emasculator*. These larvae seemed well advanced in development, ranging between 10 and 15 mm. in length. Only one larva was found to a mouse. On one occasion a particularly large larva emerged from its sac in a dead mouse. The others remained within until removed in the process of skinning. The majority of the mice infested were nursing females. Only one was noticed in a male in which case the swelling caused by the subcutaneous larva superficially resembled a swollen testicle.

Baird, or prairie, deer mouse (*Peromyscus maniculatus bairdii*, Hoy and Kennicott): Eleven specimens of this mouse were secured, nine being taken in the fore dune area amid *Calamovilfa longifolia* and *Prunus pumila*, and two in an interdunal meadow. The latter were caught in traps set near holes that appeared to have been made by crayfish. Besides the two captured in this meadow a third got into a trap and left only its tail. None of the traps set in this meadow secured *Peromyscus leucopus noveboracensis* or other mammals. With the exception of two house mice, the Baird deer mouse was the only mammal taken in the fore dunes. Traps set at the top of a blowout about 150 feet above the lake and where much *Calamovilfa* was growing yielded only the northern deer mouse. The Baird deer mouse does not appear to be very common. On one occasion 80 traps were placed in the fore dune area and not a specimen of any kind was secured and on another occasion 78 traps were placed in the fore dunes and only two of this species and a house mouse were secured. Hahn (4) did not find this species very common in the state, recording it from only five counties. Evermann and Clark (3) record three specimens from Lake Maxinkuckee region and state: "It is very abundant in the sand dunes that border Lake Michigan".

What these mice do with themselves during the day, at least in the fore dune region, is difficult to say, unless they dig down into the sand. Only once I found what appeared to be a burrow. A trap placed near it yielded nothing. As the habitat of these mice is much sandier than that of the northern deer mouse their nightly activities were much more visible. Judged by the large number of foot prints and the small number

of mice taken the individual mice are quite active. Like the other species of deer mouse their usual mode of progression is by jumping on all four feet at once. Only rarely does one find tracks apparently made by

Fig. 1. Course of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, in dry sand.

walking, in which case what appear to be tail marks are sometimes present. In the jumping mode of progression the tail does not touch the ground. There seemed to be a tendency for the animals to jump along the same course or else for the same animal to jump back and

Fig. 2. Footprints of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, in dry sand.

forth along it. The sand was often well marked by their tracks into almost a runway, usually in a direction parallel to the axis of the low dunes.

The mammae are pectoral 1/1 inguinal 2/2=6. Of the four females

taken only two were adult, one was nursing and the other contained four fetuses, each about 20 mm. in length.

This species although closely resembling the more common northern deer mouse is readily distinguishable in the adult state by its darker coloration and more sharply bicolored tail, as well as by its smaller size, shorter hind foot, and shorter tail. Immature specimens of the two species are almost indistinguishable in point of color, but are apparently easily distinguished by measurements. Five adult or nearly adult males give these extreme and average measurements: total length 150, 141, 130; tail 62, 57, 52; hind foot 18, 17.7, 17 mm. Two adult females measure respectively, 148, 137; 60, 52; 17, 18 mm.

One of the specimens of this species was infested in the inguinal region with a fly larva, similar to the one found in the northern deer mouse.

Fig. 3. Habitat of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, the low fore dunes in the foreground covered with *Calamovilfa longifolia*.

Prairie vole (*Microtus ochrogaster* Wagner): Represented by seven specimens, three adult or nearly so and four young. Three of the specimens, an adult and two young were taken in a wooded dune, though near a meadow, in subterranean runways in traps specially set for pine voles. The others were taken in an interdunal meadow in traps placed at random on the ground as no runways were discernible. Although traps were placed in four different interdunal meadows, in only one were these voles taken. It may be that colonies are somewhat local in distribution. One female was nursing, mammae: pectoral 1/1, inguinal 2/2=6. Three stages of growth appear to be present, breeding adults, half grown young, represented by four immature specimens, and very young represented by those belonging to the nursing female. Hahn (4) records this vole as being rather generally and commonly distributed throughout the state. Dice (2) found it common in Berrien County, Michigan.

Pine vole (*Pitymys pinetorum scalopsoides* Audubon and Bachman): Two specimens of this species were secured, a male in a runway in damp sphagnum and cranberry at the edge of an interdunal pond, and a female taken in a wooded dune in a trap set in a subterranean runway. Upheaved subterranean runways like those made by moles are very common in the wooded portions of the dunes. On one occasion such an upheaved runway was found on top of a blowout in sand not stiff enough in places to hold up. Whether all these runways are made by pine voles can not be said. Traps placed in them yielded chiefly deer mice. One of the present species was taken in them and two *Microtus ochrogaster*. I failed to capture moles and short-tailed shrews in such runways but perhaps they were insufficiently set with traps. These two specimens of pine vole are the most northern taken in the state. Hahn (4) says he has not taken this species in the northern part of the state, Wabash County being his most northern record. Evermann and Clark (3) record one specimen from Marshall County. Dice (2) records it from Berrien County, Michigan. Measurements of the two specimens, male and female respectively: total length 122, 122; tail 22, 22; hind foot 16.5, 17.5.

Muskrat (*Ondatra zibethica* Linneaus): Some muskrats are said to be trapped for their skins each winter, being found in the subdunal great marsh and in interdunal ponds such as Little Lake and Walker Lake. In dry seasons, as in 1922, they must become quite terrestrial.

Norway, or common house rat (*Rattus norvegicus* Erxleben): No specimens seen or taken. Residents say rats are sometimes found about the outbuildings of the store at Waverly Beach. As the region becomes more populated rats will probably form a constant part of the fauna.

House mouse (*Mus musculus* Linnaeus): In spite of the large number of week-end visitors to the dunes who leave much food scattered about, and the numerous cottages toward Waverly Beach the house mouse does not appear to be common in the region. Only two specimens were secured, each in the fore dune area, one in 1921 when we were camped at Big Blowout, opposite Furnessville and over a mile from any permanent dwelling, and one in 1922 not more than 300 yards from a cottage occupied every week-end. W. D. Richardson states that the only mice he has observed in his cottage are deer mice. The adult female taken in 1922 measures: total length 172, tail 85, hind foot 18 mm.

Thirteen-striped spermophile or ground squirrel (*Citellus tridecemlineatus* Mitchill): This species is not uncommon along the Chicago, Lake Shore and South Bend Railway just south of the dunes. In the dunes proper just north of Oak Hill station and a few feet above the subdunal swamp my wife saw one of these spermophiles. It is not improbable that these animals have entered the region by following the railway and that the one seen opposite Oak Hill had followed the road leading from the station to the dunes.

Chipmunk (*Tamias striatus* Linnaeus): Chipmunks do not appear to be very common in the dunes. I have only one record of them in my notes but feel certain I have seen more than one. None were trapped though suitable traps baited with apples were set in what appeared to

be good chipmunk territory. Wood (6) says it is rare in Berrien County, Michigan, and Dice (2) seems to record but a single specimen. There is some doubt as to the race of chipmunk inhabiting Indiana. Hahn (4), and Evermann and Clark (3) refer the Indiana chipmunk to the typical form *striatus*, and former disputing McAtee's identification of it as *lysteri*. Dice (2) and Wood (6) identify the chipmunk of Berrien County, Michigan, as *lysteri*. Cory (1) gives a map showing the ranges of the different forms of the genus. According to it *lysteri* is not found in Michigan. The form in the southern portion of Indiana is *striatus* and the form at the southern end of Lake Michigan is *griseus*. The rest of the northern portion of Indiana is occupied by intermediates between *striatus* and *griseus*. As the flora of the dunes contains many northern forms of plants, and in the absence of a series of chipmunks, one is inclined to refer the dune animal to a northern race, either *griseus* as adopted by Cory or *lysteri* by Dice.

Red squirrel or chickaree (*Sciurus hudsonicus loquax* Bangs): The red squirrel is fairly common in the wooded portions of the dunes. They are often seen running about and frequently heard. Four specimens were secured, a pair of adults caught in traps baited with apples, a nearly mature individual given me by Wilbur Eklund, and a half grown young unable to take care of itself found wandering near our tent. The adult female which was trapped September 27, was nursing, (mammae axillary 1/1, pectoral 1/1, inguinal 2/2=8). As young in two stages of development were secured it may be inferred that at least two broods are raised each year. Measurements of the adult male and female: Total length 320, 320; tail 125, 125, hind foot 46.5, 47 mm.

Western fox squirrel (*Sciurus niger rufiventer* Geoffroy): This handsome squirrel is frequently seen in the wooded portions of the dunes. No specimens were secured. It does not appear to mind civilization so long as trees are abundant. There are a number of them living along some of the well treed streets of South Bend.

Woodchuck (*Marmota monax monax Linnaeus*): Woodchucks are very common almost everywhere in wooded portions of the dunes as judged by their many burrows. The animals themselves are not so frequently seen. Their burrows are never placed on the face of dunes on the lake front and I have never seen anything that might be interpreted as their tracks in the light dry sand of the fore dunes. Immediately after the establishment of wooded dunes their burrows are found either high up or just above the levels of the interdunal meadows and ponds or subdunal swamp. No attempt was made to secure specimens. The species is represented in my collection by a weathered skull picked up near the Furnessville blowout. Hahn (4) says, in southern Indiana the woodchucks "usually retire about the middle of October". The first five days of October 1922 were unusually warm, our Six thermometer recording daily maxima of 78, 84, 80, 80, and 86°F. respectively, after that the weather became cooler though not cold. A woodchuck was seen on October 4 and up to the time of the cooling weather fresh tracks appeared about their burrows. After that date woodchucks were not seen and frequent rains interfered with seeing whether their burrows

had been freshly used. W. D. Richardson says he saw a woodchuck as late as the last of October or first of November, 1922. In the dunes I have never seen any evidence of essential damage to plants attributable to them. They certainly are much less destructive than man. It is a pity they do not show themselves oftener than they do.

Mearn's cottontail (*Sylvilagus floridanus mearnsii* Allen): Cottontails seem fairly common in the region. I have seen them in nearly every locality except the fore dunes. On two occasions I saw cottontails running from the red osier dogwood and fox grapes near our tent as we were returning late in the afternoon. They may have been attracted by the fox grapes which were trailing over the sand. No specimens were secured.

Virginia deer (*Odocoileus virginianus* Boddaert): The Virginia deer has been extinct in the region under consideration for many years. H. W. Leman of Chicago, who is much interested in the dunes and owns a large tract of land along the lake front west of Waverly Beach, says that one of his Chicago friends, now dead, told him that when he was a young man there was excellent deer shooting in the dunes. If his friend were living he would be about 75 years of age. One may conclude from this that deer were fairly numerous in the dunes about 1875. They were probably all killed off shortly after that time. If they persisted for ten years longer the date of their disappearance would be only a few years earlier than the last record for Jasper and Newton Counties, 1890 and 1891 according to Butler (4). Their former abundance in the region is attested by remains which are not infrequently found. In his cottage in the dunes H. W. Leman has a very perfect antler picked up in the sand. Miss Rose Leal of Chicago gave me a nearly complete antler which she had picked up in a blowout. Its length following the convexity from burr to broken tip is 320 mm., circumference just above the burr 85 mm. In a blowout adjacent to our camp I found three fragments of antlers not quite so large. With them were various badly weather-worn bones and two molar teeth. Whether all the fragments came from one animal cannot be said. In another blowout to the west I picked up two molar teeth and portion of metatarsals and metacarpals and vertebrae. With these evident deer bones were a fragment of lower jaw of a member of the genus *Canis*, probably a large dog rather than a wolf and the upper end of the femur of possibly a dog. In a blowout near Waverly Beach F. E. Challis collected numerous fragments of deer bones. At the water's edge when the lake was unusually low I picked up an almost perfect left ramus of a deer's mandible. Part of the symphysis is present but none of the incisor or incisor-like teeth, but the cheek teeth are all in place and essentially perfect. The length of this toothrow (alveoli) is 83 mm. The last molar is slightly worn, the teeth anterior to it moderately so. It is said that in the public library of Gary there is a very complete pelvis of a deer found in the dunes by Boy Scouts.

Mammals Almost Certain to be Found in the Dune Region of Porter County, but Concerning Whose Occurrence There is no Satisfactory Evidence at the Present Time in the Nature of Specimens Collected or Observed.

Little brown bat (*Myotis lucifugus* Le Conte), Say bat (*M. subulatus* Say), brown bat (*Eptesicus fuscus* Beauvois), silver-haired bat (*Lasionyceris noctivagans* Le Conte), hoary bat (*Nycteris cinera* Beauvois), Pennsylvania vole (*Microtus pennsylvanicus* Ord), jumping-mouse (*Zapus hudsonius* Zimmerman), flying squirrel (*Glaucomys volans* Linneaus), gray squirrel (*Sciurus carolinensis* Gmelin).

Existing Mammals Which Probably Occur or Have Lately Occurred in the Dune Region of Porter County.

Star-nosed mole (*Condylura cristata* Linnaeus), long-tailed shrew (*Sorex personatus* Goeffroy,) small short-tailed shrew (*Cryptotis parva* Say), lemming mouse (*Synaptomys cooperi* Baird), badger (*Taxidea taxus* Schreber). The badger was noted by Wood (6) in Berrien County, Michigan, as late as 1917. A. E. Didelot who is quite familiar with badgers from experience in Wyoming and has information of most of the animals trapped about Waverly Beach and Chesterton, knows of none having been taken in the region.

Mammals Not Now Extant in the Dune Region of Porter County, but Whose Remains May Possibly be Found Buried in the Sand or in the Swamps.

Fisher (*Martes pennanti* Erxleben), black bear (*Ursus americanus* Pallas), otter (*Lutra canadensis* Schreber), puma (*Felis cougar* Kerr), Canada lynx (*Lynx canadensis* Kerr), bay lynx (*L. ruffus* Gueldenstaedt), porcupine (*Erethizon dorsatus* Linneaus), varying hare (*Lepus americanus* Erxleben), bison (*Bison bison* Linneaus), elk (*Cervus canadensis* Erxleben).

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REACTIONS TO LIGHT AND PHOTORECEPTORS OF LUMBRICUS TERRESTRIS.

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It is generally known that earthworms are sensitive to light, but comparatively little is known concerning the nature and distribution of the photoreceptors.

It has been shown by numerous workers that worms of this species are negative to all ordinary intensities of light. In fact, the nocturnal habits of these animals indicates that they can distinguish between light and darkness, and since they are nocturnal in habit they must be negative in their normal reactions to light of the intensity of daylight.

Although lights of ordinary intensities cause these animals to react negatively, lights of very low intensities have an opposite effect. When normal worms were exposed to a light of about .00118 meter candle power, which was covered by a yellow glass, the worms were no longer negative but showed a definite majority of positive reactions. These positive reactions to very weak lights are certainly in keeping with the nocturnal habits of these worms.

Injury to the brain by removal, by removal of one lobe, or by severing the circumesophageal commissures, resulted in these worms losing their power to react negatively. In fact, under such conditions these worms are fully as strongly positive as normal worms are negative.

If the ventral nerve cord of an earthworm is severed, as between segments four and five by a slight ventral incision, the animal is now really physiologically double so far as its reactions to light are concerned; the first four segments being definitely negative and those caudal of segment four are definitely positive.

These results show that the seat of negative reactions resides in the brain and when this center is injured or destroyed the worms no longer respond negatively but become positive in their reactions to ordinary lights.

Now let us turn our attention to other experiments in order to discover if possible the regions of the body that are most sensitive to light, for the purpose of determining the distribution and nature of the photoreceptors.

By the use of ordinary illumination it is possible to demonstrate that worms of this species are most sensitive to light in their anterior regions, somewhat less in the posterior and least of all in the middle portions of their bodies.

By means of a strong pinhole light, the prostomium and the three anterior segments were found to be most sensitive, of which the prostomium appeared to be slightly more sensitive than the rest. Although all segments were found to be photosensitive, each segment, with the possible exception of the first three and the last one or two, was most sensitive in the middle portion of the dorso-lateral region. No reactions were obtained by illuminating the mid-dorsal areas except those of the twelve anterior and the three posterior segments. The

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worms did not react to illumination on the mid-ventral surface except on the three anterior and the last segment.

Some of these conclusions were confirmed by tests made, following the removal of certain anterior segments and certain parts of the nervous system.

A comparison of the histological structure of the more sensitive with the less sensitive regions, revealed the fact that a rather peculiar type of sense-cell is more abundant in the former than in the latter areas. This indicates that these sense-cells are photoreceptors.

CHROMOSOMAL VARIATIONS IN THE EARWIG, ANISOLABIS ANNULEIPES LUCAS.

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The specimens for the following study were collected in the locality of New Orleans, La. and Mississippi College, Miss. The study, however, was based largely on the Louisiana material. The specimens were identified as *Anisolabis annuleipes* Lucas by A. N. Caudell, Bureau of Entomology, Washington D. C. The gonads were fixed in Flemming and the sections were stained with Haidenhain's hematoxylin and a few were counter-stained with eosin. All the work was done under the direction of Dr. Fernandus Payne to whom the writer is greatly indebted for helpful criticism and advice.

Several workers beginning with Carnoy in 1885 have described the spermatogenesis of the European earwig and there has been much disagreement in the descriptions and explanations of the various authors. Payne[1] reworking the spermatogenesis proves beyond a doubt that many irregularities do exist in this species and in this way accounts for some

Fig. 1-4. Spermatogonial metaphase showing 25 chromosomes.

of the disagreement of the preceding workers. Although the following study does not have a direct bearing on these explanations, nevertheless it does definitely show certain irregularities and probably with a more extended study of several species of earwigs we may find that most of the chromosomal irregularities of this whole group of insects will become understandable. The writer is at present working on a comparative study of the spermatogenesis of the earwigs.

Description. The spermatogonial number in *Anisolabis annuleipes* Lucas is 25 (figs. 1, 2, 3, 4). This was shown to be the case by a great many counts of clear metaphase plates.

During the growth period one or more dark staining bodies are seen in the nucleus (figs. 5, 6, 7). By following these bodies during this period and the early prophases it was found that one body very definitely continues as a bivalent chromosome. As shown in figures 8 and 9 the parts of the bivalent are not of equal size. The dark staining body and its changes in the growth period and early prophase is similar to that described by Payne in the European earwig except that he did not find the body bilobed. In the latter part of the prophase this unequal pair of chromosomes, which the body very definitely

[1] Payne, Fernandus. Chromosomal Variations and the Formation of the First Spermatocyte Chromosomes in the European Earwig, Forficula sp. Journal of Morphology, Vol. 25, No. 4.

"Proc. 38th Meeting, 1922 (1923)."

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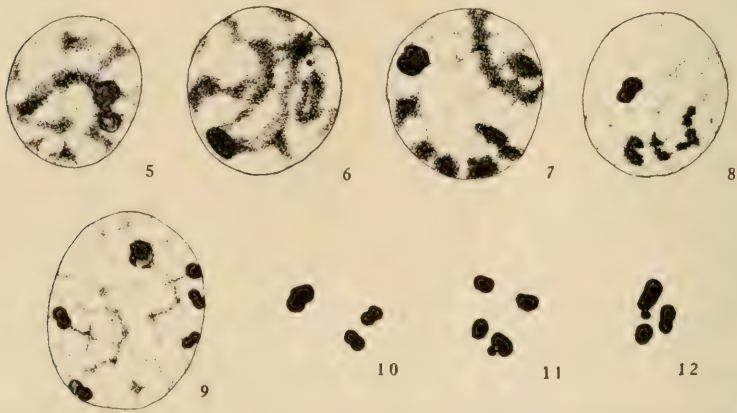
becomes, is seen occasionally to break up into a large bivalent and a small univalent chromosome (figs. 11, 12). The separation of the small univalent from large bivalent seems to take place in only a small percentage of the dividing cells while a condition similar to figure 10 is very often found.

With the spermatogonial count of 25 it would be expected that the metaphase counts of the first spermatocyte division would show 13, but such was not the case except in a small percentage of the counts. By counting only clear metaphase plates it was found that 92 per cent showed 12 chromosomes (figs. 13, 14). The study of the side views of the metaphase division showed clearly that the univalent chromosome did not lie in a different plane from that of the bivalent chromosomes nor did it pass to the pole before the division of the bivalents as has been described in several instances. In a very few of the cells examined it was found that a small univalent chromosome could be seen in the



Figs. 5-12. (5, 6 and 7), Growth period showing dark staining bodies; (8 and 9), prophase, dark staining body becoming unequal pair; (10), later prophase showing unequal pair; (11 and 12), small univalent separating from bivalent chromosome.

side views (figs. 17, 18). This accounts for the small percentage of 13 counts (figs. 15, 16).

The metaphase counts of the second spermatocyte division showed no such irregularity in chromosome behavior as that found in the first spermatocyte division. Of the 513 counts made of this division 280 showed 12 (figs. 32, 33) and 233 showed 13 (figs. 34, 35). A study of the side views of the division showed that all the chromosomes divided normally.

From the above facts it appears that the real problem here would be to account for the disappearance of the univalent chromosome that was present in the spermatogonial metaphase and its reappearance in the second spermatocyte division. The second spermatocyte counts showed nearly equal numbers of twelve and thirteen chromosomes. This is just what would be expected when the spermatogonial number is 25.

In the growth period and early prophase one of the dark staining bodies was seen to give rise to an unequal pair of chromosomes. This

unequal pair passed normally into the metaphase stage. With the condition described by Payne in mind, where the larger end of the unequal pair showed a bilobed appearance, it was thought that some such condition might be found here. A careful study of the side views showed no such condition, however. It was found that a slightly unequal pair did exist and that this pair started to divide shortly after the other pairs. Figures 11 and 12 of the prophase show the unequal pair breaking up into a large bivalent and a small univalent chromosome. Figures 17 and 18 show the small univalent chromosome in the metaphase. The separation of the univalent chromosome as shown in the above figures accounts for the normal thirteen count that was found in a small percentage of cases (figs. 15, 16). Another abnormality that was found in the side views of the first spermatocyte division was the large number of lagging chromosomes. This species differs in this respect from the European species in that the lagging chromosomes were found in the first spermatocyte division only, while in the latter they were found to occur in both spermatocyte divisions. One lagging chromosome was found in the second division but this evidence has been disregarded because of the probable pathological condition of the specimen. This pathological condition was quite evident in other cysts of the same testis. The form of the lagging chromosomes was seen to vary a great deal from a single elongated mass to that of a more or less trilobed condition (figs. 21-28). It was noticed as stated above that the unequal pair divided somewhat later than the other pairs. By tracing this unequal pair from the metaphase to the anaphase the evidence seemed to warrant the conclusion that the lagging chromosomes were these unequal pairs that were dividing irregularly. Figure 25 shows an unequal pair dividing into an upper single mass and a lower mass that is somewhat bilobed. Figures 23, 24 and 26 also indicate this condition. Figures 27 and 28 are serial sections of the same cell in anaphase. By counting the chromosomes in both figures the lower part shows definitely 12 chromosomes while in the upper part are 11 chromosomes and the bilobed chromosome that is slightly lagging. If this lagging individual is the unpaired univalent plus one half of the divided bivalent we have, then, 12 chromosomes passing to the lower pole and 13 to the upper. This is just the distribution that would be expected with the 25 chromosomes in the spermatogonial division. That the univalent chromosome becomes attached to one of the autosome pairs causing this lagging in the first spermatocyte division is further evidenced by the condition shown in figures 23 and 26. In figure 23 an enlargement on one side of the lagging chromosome is very noticeable. Figure 26 is a later anaphase than figure 23. Here the lagging chromosome has divided but the parts still lag behind the autosomes. The upper chromosome is much smaller than the lower and the irregular outline of the lower mass resembles the upper part of the lagging chromosome in figure 23. One suggestion the writer might offer to account for these lagging chromosomes is that it is determined by the position of the attachment of the small univalent chromosome to the larger autosomes. When the small chromosome becomes attached so as to adhere to both autosomes the three chromosomes assume the linear arrangement in early

anaphase and later the whole mass is drawn out into the characteristic strand shown in figure 21. Later anaphase show that these lagging chromosome groups finally divide unequally and pass to the poles losing their identity in the condensed mass of chromosomes of the late anaphase (fig. 29).

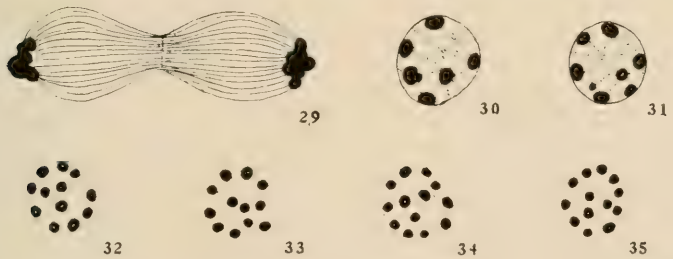
The above explanation of the lagging chromosomes is not offered to explain a condition of similar appearance found in other forms but applies only to *Anisolabis annuleipes*. The writer does not offer the suggestion to explain the presence of two lagging chromosomes which

Figs. 13-28. (13 and 14), Metaphase polar view showing 12 chromosomes; (15 and 16), same showing 13 chromosomes; (17 and 18), side views showing small univalent; (19 and 20), side views of unequal pair; (21, 22, 23 and 24), side views of anaphase with lagging chromosomes; (25 and 26), division of lagging chromosomes; (27 and 28), serial section of a cell in later anaphase showing bilobed chromosome.

are only very rarely found in this species. Since the few cells with two lagging chromosomes seemed to degenerate in late anaphase the writer concludes that these cells fail to complete the maturation divisions.

Following the first spermatocyte division the nucleus passes through a short rest period before the second spermatocyte division (figs. 30, 31). A careful study of the nucleus from anaphase of the first to the metaphase of the second spermatocyte divisions was made. During the condensed appearance in the late anaphase the chromosomes could not be traced (fig. 29). In the reorganization of the nucleus the chromosomes separate and remain as distinct bodies distributed through the nucleus until the prophase of the second spermatocyte division. After this

reorganization a chromosome much smaller than the others can be seen. Figure 31 shows this small chromosome. This stage seems to be later than that shown in figure 30 where the small individual lies against the large chromosome. Conditions similar to these figures are very common in the cysts showing the rest stage. No great difference was found in the sizes of the chromosomes in the metaphase plates showing 12 chromosomes (figs. 13, 14) but in figures 15 and 16 showing metaphase plates with 13 chromosomes one small chromosome can be seen. This would indicate that the attached univalent was much smaller than the other chromosomes and this difference in size should make it noticeable at once when it became detached. On the basis of size the small body appearing in the rest period (figs. 30, 31) seems to be the univalent chromosome. Further study shows this small element behaving in the prophase of the second spermatocyte division as the other chromosomes. This seems to warrant the conclusion that the small univalent that disappeared prior to the first spermatocyte division became attached



Figs. 29-35. (29), Late anaphase showing chromosomes in condensed mass; (30 and 31), rest stage between first and second spermatocyte divisions showing very small chromosome; (32 and 33), second spermatocyte metaphase with 12 chromosomes; (34 and 35), same showing 13 chromosomes.

to one of the autosome pairs and remained attached until the reorganization of the nucleus in the telophase of the first spermatocyte.

Since the specimens were collected fairly late in the season some of the testes were filled with mature spermatozoa and many of the others had few cysts with cells in division. Although all the stages described above could be traced in many specimens there were a few that had several cysts in metaphase that permitted a large number of counts per individual. A description of one typical specimen with several cysts in metaphase might be of interest here. Specimen 40 seems to be of interest in this connection. Only one clear count of the spermatogonial metaphase could be made. It showed very definitely 25 chromosomes. The description of the growth period given above could be applied to this specimen (figs. 5, 6 and 8) although very few prophase groups similar to figures 11 and 12 were found. Here all of the 14 clear metaphase counts in the primary spermatocyte showed 12 chromosomes. The one cyst in the rest stage between the first and second spermatocyte divisions showed clearly many stages the close association of the small chromosome and the large one similar to figures 30

and 31. In the secondary spermatocyte there were 69 polar views of the clear metaphase plates. Of this number 37 showed 13 and 32 showed 12 chromosomes (figs. 32, 34 and 35). This is just what would be expected where there were very few cases of the prophase separation of the small univalent and the large bivalent chromosomes (figs. 11 and 12). The metaphase counts alone show very definitely that the univalent chromosome behaves irregularly prior to the second spermatocyte. No lagging chromosomes were seen in this specimen.

The above evidence leads to the conclusion that the small individual seen in the resting stage and early prophase of the second spermatocyte becomes attached to one side of the large chromosome pair sometime between the metaphase of the spermatogonial division and the prophase of the primary spermatocyte. Although this attachment has not been observed it probably takes place very early in the growth period. These attached chromosomes form the larger end of the unequal pair. Occasionally the chromosomes become detached allowing all pairs to divide normally while the univalent chromosome passes undivided to one pole giving the 13 chromosomes in the first spermatocyte metaphase. Nothing can be said with certainty as to the mode of attachment although the small chromosome seems to be plastered to the side of the larger chromosome so as to show no break in the general outline of the mass except for a slight enlargement (figs. 19 and 20). It might be expected that the attachment of the univalent chromosome to one-half of the autosome pair would make a very noticeable enlargement but such was not the case. Figures 17 and 18 show the univalent chromosome unattached but near one of the large autosome pairs. Assuming that the small chromosome was plastered to the upper half of the large bivalent chromosome the resulting mass would not be greater than the larger end of the unequal pairs shown in figures 19 and 20. After the condensed condition in the anaphase of the first spermatocyte division (fig. 29.) the chromosomes separate as individuals from this chromosomal mass and remain separated to divide normally in the secondary spermatocyte. This accounts for the unusual number of 12 chromosomes in the first spermatocyte and the normal number of 12 and 13 chromosomes that appears in the second spermatocyte.

It is interesting to note that the same numerical condition has been found in the distribution of the chromosomes of *Anisolabis maritima* by Kornhauser[2].

[2] Kornhauser, S. I. Cytology of Anisolabis maritima. Abstract of Papers, American Society of Zoologists 1920.

A HYGROTHERMOGRAPH PUZZLE.

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In the course of the investigation of some biological problems it is frequently desirable to secure temperature and humidity records for possible correlation with the behavior of the individuals under observation. At a one man observation station it sometimes happens that the attendant's services are badly needed elsewhere on the particular day, usually Monday, when the record sheets of recording instruments are to be changed. In order to take advantage of such occasions and at the same time have the records continue uninterruptedly, a scheme was

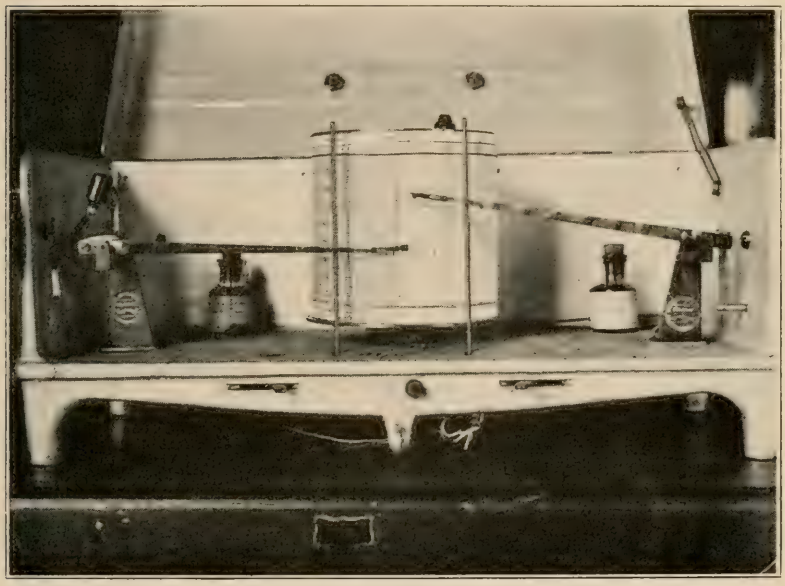

Fig. 1. Hygrothermograph showing the recording pens in position as they pass from the old to the new record sheet without interruption of records.

originated by which the attendant could put on the new record sheet before his departure and so arrange it that the graph would continue from the old to the new sheet on Monday without further attention.

On the day of departure the clock is wound and a new record sheet is placed in position in the usual manner. Most of the used portion of the old sheet is folded under so that the new sheet is left exposed until the same day of the following week. The edge of the unused portion of the old sheet is folded snugly under and arranged so that the respective time arcs and horizontal percentage or degree lines are coincident with those of the new sheet. (See Fig. 1.)

The bar which usually is furnished to hold the record sheet in place can very well be replaced by strong elastic bands at the top

"Proc. 38th Meeting, 1922 (1923)."

and bottom of the cylinder. These have been found to hold the sheets more snugly to the cylinder in most cases than does the bar. The recording pens are then set to continue the graphs on the old sheet and when it is finished they pass on to the new sheet in their proper respective positions. When the attendant returns, the old record sheet is removed and the new one is left in place for records until the next regular time for change.

By actual test with the record sheets thus arranged and snugly adjusted to the cylinder, the acceleration caused by the extra thickness of paper due to the folding of the old record sheet, was found to be scarcely, if at all perceptible even for the accumulation of a period of three days.

NAGANA (*TRYPANOSOMA BRUCEI*): THE COURSE OF THE DISEASE IN LABORATORY ANIMALS WHEN INJECTED WITH CULTURES GROWN *IN VIVO* AND *IN VITRO*.

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Nagana, or Tsetse fly disease, as it is correctly called, is due to a specific trypanosomal parasite. It occurs naturally in many parts of Africa, and its causative agent, which was discovered by Bruce in 1894, bears the scientific name of *Tryanosoma brucei*.

Normally the parasite exists in the blood of certain animals which apparently have a marked tolerance for it, thus serving as its natural source of infection.

Most mammals are susceptible to Nagana with the exception, however, of man. The parasite can easily be perpetuated *in vivo* by resorting to the ordinary laboratory methods of inoculation. And also since the trypanosome can be cultivated *in vitro* upon blood agar medium, as Novy and MacNeal[2] first demonstrated in 1903, it lends itself ideally for experimental work. It is very interesting not only because it is a disease of distant Africa and due to a special type of parasite, but also because of the fact that it gives to a trypanosomiasis occurring in very distinct forms depending primarily upon the species of the animal and the virulence of the organism.

The source of the strain of *Trypanosoma brucei* used in our experiments is from an infected dog sent by Bruce to England in November, 1896, and it was this parasite which Novy and MacNeal used in their cultivation experiments.[3]

There are three distinct varieties of the disease:

First, the acute type which occurs in the rat, mouse, field mouse (Arvicola), marmot, hedgehog, dog, cat, squirrel and monkey.

Second, the subacute type which develops in the rabbit, guinea-pig, field mice (*Mus sylvaticus, Arvicola arvalis*), garden mouse (*Eliomys quercinus*), equine, and pig.

Third, the chronic variety which occurs in cattle, goats, sheep, geese and fowls.

Table I lists some of the animals susceptible to Nagana.

In an acute infection, the trypanosome makes its way into the blood in from one to several days. Following this infection the number of parasites usually increase constantly and regularly until the death of the host, which may occur in a few days, or a week, or even longer.

The subacute course of the disease is quite different for while the parasites do not appear in the blood as soon as in the acute form their development is not rapid and continuous for they may practically dis-

[1] Contribution from the Bacteriological Laboratory, Purdue University, Lafayette, Indiana.

[2] Jour. Amer. Med. Assn., 1903, 41, p. 1266; Jour. Infect. Dis., 1904, 1, p. 1.

[3] This work was made possible through the kindness of Dr. F. G. Novy, Professor of Bacteriology, University of Michigan, from whom trypanosomal blood was obtained.

"Proc. 38th Meeting, 1922 (1923)."

appear and reappear and repeat this activity several times before they may or may not become extremely numerous shortly before the death of the animal. The organism may be first seen in the blood stream in about two or more days and the extent of the disease may be from less than two to many weeks.

TABLE I. Showing the Results of Different Animals Infected with Nagana.

Animal	Method of Injection	Period of Incubation Days	Duration Days
Rat	S. C.	2	3½–5½
	I. P.	Less than 1	2½–3
Mouse	S. C.	2	3½–5½
	I. P.	Less than 1	2½–3
Field mouse (*Arvicola arvalis*)	S. C.	2–6	4–12
(*Mus sylvaticus*)	S. C.	8	30
Dog	S. C.	4–6	14–26
	I. P.	2–4	6–14
Cat	S. C.	4–5	19–44
	I. P.	2–4	14–28
Guinea-pig	S. C.	2–7	7–78
	I. P.	1–3	5–61
Rabbit	S. C.	6–8	13–89
	I. P	2–3	10–75
Horse	S. C.	7–8	15–92
	I. P.	4–5	8–49
Ass	S. C.	7–8	15–92
	I. P.	4–5	84
Cattle	S. C.	5	Months—may recover
Sheep	S. C.	3	6½ months—may recover
Monkey (Macacus)	S. C.	4	15
Hedgehog	S. C.	4	13–17

S. C.—Subcutaneous inoculation.
I. P.—Intraperitoneal.

In the chronic infection the trypanosome appears as a rule several days after the inoculation and then after running a very irregular course for months, during which time only very few organisms are usually observed, they may disappear entirely and the animal recovers.

Technique of Studying Trypanosomes in Living Condition.—Since the parasites are usually present in the blood stream the most convenient method of obtaining blood is employed. When the organisms are numerous in the blood a very small amount will suffice to reveal their presence.

In case of the rat and mouse the tail is clipped while in that of the dog, rabbit and guinea-pig a blood vessel in the ear may be pricked or a small incision made in the ear. A drop of the fluid is placed on a slide or cover-slip and by gentle pressure a one layer preparation, which is usually desirable, is obtained. At times, however, when the parasites are very scarce a heavy preparation will aid in identifying their presence by the movement of the red blood cells.

This simple preparation is excellent for making a hasty examination but currents are soon set up in the liquid due to desiccation, thus rendering further examination quite impossible. If longer observations are desired the preparation may be rimed with paraffin or a hanging-drop or the Ranvier slide preparation resorted to.

When, however, the trypanosomes are extremely scanty in numbers diagnosis cannot be made by this simple procedure, although repeated examinations are continued on successive days. In such cases the animals are bled for a larger amount of blood which, after defibrinating or chemically treating to prevent coagulation, is centrifuged at high speed. The parasites, if present, will be found just above the red blood cells.

The blood of the suspected animal may be inoculated into very susceptible animals and in turn their blood may be examined for trypanosomes. Stained blood smears may aid in establishing the development of trypanosomiasis.

At times the examination of the oedematous fluid or serous exudate from the lesions will reveal the presence of the parasite.

Inoculation of Animals with Cultures Grown in vivo.—Since in this work the common laboratory animals were used, as the rat, mouse, dog, rabbit and guinea-pig, the course of the disease will be described as it occurred in these animals.

Experiments with rats.—When a very susceptible animal as the rat or mouse are injected with the trypanosomal blood they, of course, succumb from the acute variety of Nagana. The period of incubation, that is the first appearance of the trypanosome in the blood stream after the inoculation, is usually 18 to 24 hours. From this time on the number of parasites increase at an enormous rate until death, which occurs in two and a half to five days, depending largely upon the virulence of the organisms, numbers injected and their avenue of introduction into the animal. Just before the fatality which is always certain, the organisms are as numerous as and even greater than the number of red blood cells.

If rats or mice are inoculated with trypanosomal blood from other animals such as the guinea-pig or rabbit, the virulence of the parasite for the former animals is somewhat attenuated as is evidenced by a slightly longer period of incubation, usually two to three days, and death does not occur until six or eight days. However, After the organism makes its appearance in the blood stream its development is about the same as that in a rat or mouse which had received the trypanosome from the blood of an animal of the same species.

In a period extending over nine years in which over 1,200 rats were used, the minimum period of incubation was about ten hours and

the maximum 74 hours, while the minimum duration of the disease was 20 hours and the maximum about 140 hours. The average period of incubation was about 23 hours and the average duration 80 hours.

During the course of the disease these animals seem to be normal except possibly during the last day when they may be more or less drowsy. There are no morbid symptoms or lesions and both rats and mice may or may not die with convulsions. They are, however, excitable and if excessively annoyed convulsions usually occur just previous to death.

Experiments with dogs.—Probably the dog is the most susceptible animal, excepting the rat and mouse. If the duration of trypanosomiasis is short, only a week or two, the development of the parasites is rapid and regular. On the other hand, if the disease runs along for three or more weeks there may be an increase in the number of trypanosomes at first, followed by an abrupt decrease, but at no time does the parasite entirely disappear from the blood stream. In this respect it is unlike the subacute or chronic variety of the disease. There may be several such relapses followed usually by a marked increase before death.

In the four dogs used in the experiment (table II) the minimum period of incubation was two to four days, the maximum seven to nine days; the minimum duration of the disease six days and the maximum duration 26 days. The average period of incubation was 4.3 to 6.3 days while the average duration was 16.3 days. The animals seem to become extremely weak and there is a loss in weight. There is marked hypertrophy of the inguinal glands, the vision appears to be disturbed and there is a rise in temperature.

Inoculation with Cultures Grown in vitro.

The medium employed to obtain this strain of *Trypanosoma brucei* was a modification of the original Novy and MacNeal blood agar. The isolation was obtained by using a pea and bean blood agar or a serum agar as described by the author in 1916.[1] The parasite after becoming well established outside of the animal was perpetuated upon blood agar medium.

TABLE II. Inoculation of Dogs with Cultures Grown *in vivo*.

No. of Dog	Weight, Gm.	Period of Incubation, Days	Death, Days	Weight After Death Gm.
1	5500	7–9	26	5000
2	3210	4–6	20	2970
3	3050	4–6	13	2950
4	3090	2–6	6	3090
Average	3712.5	4.3–6.3	16.3	3502.5

[1] Proceedings of the Ind. Acad. of Sci. 1916. pp. 264-271.

Experiments with rats.—From the foregoing it will be noted that the rat always succumbs from the acute form of the trypanosomiasis when inoculated with the blood strain of the parasite. When, however, it is injected with cultures grown *in vitro* the disease may be drawn out to the subacute and in some cases to the chronic variety of the disease. This is apparently due to the generation and age of the culture, temperature at which it was incubated and the number of trypanosomes introduced into the animal.

Rats inoculated with generation one of *Trypanosoma brucei* show variable results primarily due to the age of the culture. The possibility of the original blood survival being present is not taken into consideration although this may be actually the case. They have been observed but proven to be avirulent.

Infection can usually be produced when cultures of that generation are injected that are 6 to 11 days old. Cultures older than that are non-infective.

The period of incubation, as well as the duration of the disease varies. The former lies between four to eight days and the latter may be from 8 to 14 days. Whereas, if generation two, seven days old, which is the time of its maximum growth, is injected the period of incubation is three to seven days and the time of death is seven to ten days. The variations in the period of incubation and in the duration of the disease that have been noted when rats are injected with generation two are even more irregular when inoculations with subsequent generations are made. The higher the generation the greater the variations. Thus, the average period of incubation in rats receiving generation two is 4.6 days and death occurs in an average of 8.9 days.

Rats inoculated with subsequent generations gradually show a longer period of incubation and the time of death is deferred. With generation 40, the former was 12 to 13 days and the latter was 21 days, although with generations 50 to 57 and 61 the organism seems to have become temporarily exalted. The rats receiving the culture of these generations showed periods of incubation varying from five to nine days. In the rat receiving a seven day culture of generation 89 the parasites were present in the blood in six days and the animal did not die until the 94th day. Again, in the case of generation 154 the period of incubation was eight to ten days and death did not occur until on the 126th day. With generation 190 the rat became infected on the sixth to seventh day and died on the 78th day.

This variation seemed especially more pronounced if the cultures were incubated 14 or even 21 days before inoculations were made. This is nicely shown with generation 85. The period of incubation when a seven day old culture was used was six days, death occurred on the 41st day. If the age of the culture is 14 days the trypanosomes appear in the blood of the rat at about the same time (seven days) but the animal did not die until on the 84th day. And if a 21 day old culture of the same generation was used the period of incubation was 8 to 11 days with death coming on the 51st day. In one exceptional case, that of a 21 day old culture of generation 93, the rat became infected be-

tween the 11th and 14th day and after having the disease for 250 days the animal died on the 265th day.

In all cases where the cultures were set aside for 28 days the trypanosomes became so attenuated and scarce that no infection followed their injection.

These results lead one to conclude that the higher the generation of the organism the greater its attenuation and consequently the longer the duration of the disease. However, like in all experiments of this kind the individual susceptibility of the animal plays an important rôle. Thus, of two rats inoculated with a seven day old culture of generation 154 the duration of the disease in one case was 116 days and in the other it was only ten days. A rat receiving a seven day old culture of generation 85 became infected on the sixth day and died 35 days later. A single inoculation with a 14 day old culture gave a period of incubation of seven days and death occurred on the 84th day, while a rat which suffered from the infection with a 21 day old culture of the same generation (85) showed an 8 to 11 day period of incubation and death resulted on the 51st day.

As in the case of rats becoming infected with the blood strain of the parasite, those that succumb from the blood agar strain, no matter how long or short the duration of the disease, seemed invariably not to develop the common symptoms of Nagana, such as fever, oedema and anaemia.

Experiments with mice.—It has been shown that mice, like rats, when inoculated with trypanosomal blood develop the same type of the disease and as would be expected they respond in the same manner when injected with the test-tube strain. Of 14 mice inoculated intraperitoneally with seven day cultures of generations 143, 144, and 145, the minimum period of incubation was four to six days and a maximum of 8 to 12 days, an average of about 6.4 to 8.6. The minimum time of death was nine days, the maximum 23 and the average about 13.7 days, as will be observed in table III. And, again, like the rat, the mouse shows none of the characteristic symptoms of the disease.

TABLE III. Inoculation of Mice with Cultures of *Trypanosoma brucei* Grown *in vitro*.

Generation	Period of Incubation, Days	Death, Days	Generation	Period of Incubation, Days	Death, Days
143	5–6	18	144	8–10	14
143	5–6	13	144	8–10	12
143	7–8	17	145	6–8	14
144	4–6	9	145	6–8	14
144	4–6	15	145	8–12	14
144	6–8	12	145	8–12	14
144	6–8	23	145	8–12	13
Average ..	.....	.....	.....	6.4	8.6

Note: Each mouse received an intra-peritoneal inoculation with varying amounts of a seven day old culture.

Experiments with dogs.—Of the four dogs inoculated with varying amounts of cultures of the trypanosome, which had been cultivated approximately three years *in vitro*, three died of Nagana.

One dog, after receiving five intra-peritoneal injections, each of ten tubes, of generations 140, 141, and 142 in 16 days became infected two days after the last inoculation, or 18 days after the first. After a rapid increase in the number of parasites the dog died on the 44th day.

The second dog received a single injection of ten cultural tubes of generation 144. Unlike the first and third dogs (table IV), this animal developed a typical chronic course of the disease after a period of incubation of only eight days. The parasites were not numerous but once (ten per field) and usually present to the extent of one or two per field with frequent intermissions. Death did not occur until on the 127th day.

The third dog received but one culture and showed trypanosomes ten days afterwards. He died nine days later of the acute infection following severe sickness.

The fourth dog received one-tenth of a culture and did not show parasites in its blood at the end of 39 days when he died.

TABLE IV. Dogs Inoculated with Culture Grown *in vitro*.

No. of Dog	Weight, Gms.	Generation	Amount Injected, Tubes	Period of Incubation, Days	Death, Days
1.....	8700	140–141	5x10	2–18	44
2.....	2950	142–144	10	8	127
3.....	2900	147	1	7–10	19
4.....	2600	147	1/10	No infection	39

Inoculation of Rabbits with Cultures Grown in vivo.—Rabbits inoculated with this strain of the trypanosome usually show a period of incubation of from two to five days but sometimes the organisms are not seen by the ordinary methods of examination until on the seventh to ninth day, or in very refractive animals as late as the tenth day or even much longer (31 to 49 days in a few of the exceptional cases where the animals received very small amounts of the infective material).

Also, depending upon the susceptibility of the rabbit, the duration of the disease varies greatly. Death may occur as early as ten days or it may be deferred as long as two and a half to three months. It will be seen in table V that the average period of incubation is 8.4 to 11.9 days, while the average duration of the disease is about 40 days. The number of trypanosomes to be found in the blood of these animals is usually very few and remains so even up to the time of death. The animals run an irregular course of fever and usually show oedematous swellings which may be marked, blepharo-conjunctiva, coryza, ulceration of the skin and alopecia.

TABLE V. Rabbits Inoculated with Cultures of *Trypanosoma brucei* Grown *in vivo*.

No. of Rabbit	Period of Incubation, Days	Death, Days	No. of Rabbit	Period of Incubation, Days	Death, Days
2.7	9–10	31	1.104	24–31	75
16.11	7–9	29	6.112	10–17	60
17.11	9–10	37	1.119	9–13	44
2.20	5–7	29	10.123	7–9	35
10.28	7–9	41	2.128	7–9	42
1.36	4–7	37	5.129	5–7	21
13.44	6–7	52	2.130	9–13	58
2.46	2–5	17	1.141	13–17	49
2.47	7–9	21	16.150	19–23	64
1.54	5–7	20	1.152	42–49	90
6.64	2–3	10	8.165	7–9	32
17.64	4–5	31	8.168	7–9	39
15.65	4–5	34			
Average.....	.....	.....	.....	8.4–11.9	39.9

TABLE VI. Rabbits Inoculated with Single and Multiple Doses of Ten Tubes Cultures.

No. of Rabbit	Generation of Culture	Amount Injected, Tubes	Period of Incubation, Days	Death, Days	Remarks
1	144	10			Alive 98 days
2	145	10			Alive 95 days
3	145	10			Alive 122 days
4	145	10			Alive 111 days
5	146	10		13	
6	147	10			Alive 203 days
7	148	10	66 70		Alive 308 days
8	145-149	10x10			Alive 95 days
9	145-149	10x10	17 49	58	
10	145-147	4x10	1 12		Alive 518 days
11	146-151	10x10			Alive 110 days
12	146-151	10x10			Alive 205 days
13	146-151	10x10			Alive 205 days

Inoculation of Rabbits with Cultures Grown in vitro.—While rabbits suffer from the subacute type of Nagana when infected with the blood strain of the parasite the same does not hold true when the organism has been cultivated upon blood agar for many months.

Rabbits were not inoculated with early isolations of the trypanosomes. Seven rabbits were injected intraperitoneally with the contents of ten tubes of generations 144 to 148, inclusive, and of this set only one showed the presence of trypanosomes in its blood on the 70th day and again ten days later at which time further examinations were negative.

Out of six rabbits, each receiving multiple ten tube doses, two developed trypanosomiasis of which one proved fatal as table VI shows. Rabbit number ten, which received four bi-weekly injections of ten tubes each, revealed the presence of a small number (one per field) of trypanosomes in its blood 12 days after its first inoculation. The number of parasites increased to four per field on the 14th day and then disappeared until on the 27th, 37th, 44th and again on the 126th day when only a single individual was noted in each examination. This animal showed no symptoms of Nagana more than 500 days after its inoculation and was pronounced as recovered.

Rabbit number nine after receiving ten bi-weekly doses of ten tubes each also developed Nagana on the 49th day after the first injection or 17 days after the last injection. At this time but one trypanosome was found but 7 days later ten parasites per field were observed and two days later death occurred. This animal developed the characteristic symptoms of the disease.

Inoculation of Guinea-pigs with Cultures Grown in vivo.—The variation of the disease which has been noted in the rabbit is also markedly borne out in the case of Nagana in guinea-pigs. The parasites do not increase in numbers regularly or rapidly but they may disappear and reappear several times and finally, usually just before death, may be numerous in the blood stream. The disease, generally speaking, runs a more regular course and the organisms are more plentiful than in the case of the rabbit. Nagana is always fatal for guinea-pigs with a period of incubation from two to four or even as high as eight days, the average being a little less than four days when intraperitoneal injections are made and about five days when subcutaneously inoculated. The average duration of the infection is approximately 40 days.

Out of some 600 guinea-pigs examined the shortest period of incubation was 24 hours and the longest eight days. The duration was variable being from seven to 66 days. In the typical course of the disease and also when the infection borders the chronic variety, the guinea-pigs have more or less constant fever and develop conjunctiva which may be purulent and always alopecia which is usually marked especially along the back, around the anus and eyes. Some of the animals become very anaemic.

Inoculation of Guinea-pigs with Cultures Grown in vitro.—Guinea-pigs, like rabbits, because of their refractoriness, develop at best a chronic infection if the parasite has been out of the animal body for several years or the organism has entirely lost its virulence for these

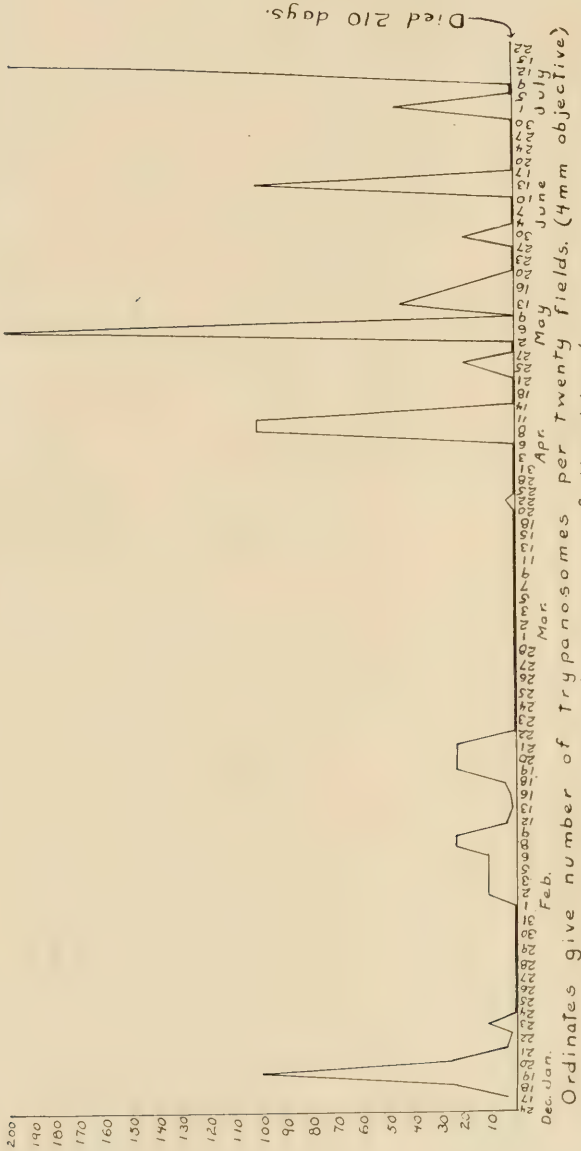
Died 210 days.
Ordinates give number of trypanosomes per twenty fields. (4mm objective)
Abscissae show dates of examination of the blood.
Dec. Jan. Feb. Mar. Apr. May June July
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10

Fig. 1. Graph showing variation in the number of trypanosomes in guinea pig number 5.190 (taken from table VIII). from date of inoculation till death. Animal was inoculated with ten tubes of generation 140.

animals but may be still pathogenic for rats, mice and dogs. *Trypanosoma brucei* if not under artificial cultivation for too long a period will infect guinea-pigs although the period of incubation and the duration of the disease is prolonged, as shown by guinea-pig 16.94 (Table VII). In this case the period of incubation was 14 to 15 days and death did not occur until on the 59th day. On the other hand of 21 animals inoculated each with one tube of generations 133 to 153, inclusive, failed to contract the disease.

It was only when the contents of ten or a multiple of one or ten tube doses were injected that a small per cent of the animals became infected, and in each case the period of incubation and the duration were markedly prolonged as shown in table VII. Thus, also demonstrating that the parasite was not wholly avirulent for the guinea-pig. Since no infection followed by the inoculation of a single cultural tube of the trypanosome in its 105th or later generation, the effect of much larger amounts of the parasites were tested out. Animals were inoculated with ten, 100, ten multiple injection of one, and ten multiple of ten tube doses of the cultural material with surprisingly few infections resulting.

Ten Tube Inoculation.—Only four out of 60 guinea-pigs or six and two-thirds per cent became infected after inoculation with ten culture tubes of generation 133 to 153, inclusive. The minimum period of incubation and duration of the disease was 18 and 50 days, respectively, as compared to the maximum of 40 and 210 days. The average period of incubation for the four diseased animals was 28½ and the average duration 117¾ days.

Course of the Infection.—The courses of the disease in these animals was interesting and since they were more or less alike and were very characteristic of the typical chronic variety of Nagana, the description of the disease of one of these animals, that of number 5.190, will be taken up in detail.

TABLE VII. Showing the Positive Results Obtained in Guinea-pigs by Inoculations with Ten or More Cultures.

No. of Guinea-pig	Generation	No. of Tubes Injected	Period of Inoculation, Days	Death, Days
16.90	40	1	14–15	59
4.190	140	10	39–40	50
5.190	140	10	21–24	210
5.147	146	10	14–18	53
6.147	146	10	28–32	158
6.68	133–139	10x1	51–92	268
5.105	136–144	10x10	7–70	104

The parasite was first seen (one twentieth per field) in the blood stream of the guinea-pig 24 days after it had received a ten culture tube dose. During the next six days trypanosomes were present although for the greater part very few in numbers. The organisms then disappeared and were not again noted until on the ninth examination after which the following 12 examinations were positive. The next 23 examinations did not reveal the presence of the parasite except in one instance when but a single individual was noted. After being present fairly numerous (five per field) in the blood stream for two days, the next three consecutive examinations were negative only to be followed by a positive observation and again by an intermission. The next examination showed the organism in greater numbers (ten per field) than in any other previous examination, however, upon the following examination the parasite had again disappeared. This was followed by five positive findings and four intermissions and the animal died on the 210th day.

Out of the 82 examinations made after the trypanosome was first observed, 32 were positive and 50 were negative during which time there were 11 positive periods and ten relapses. At no time during the course of the trypanosomiasis did the parasite exceed 10 per field which was noted but twice. Their scanty numbers, however, were characteristic as will be noted in figure 1.

One Hundred Tubes Inoculations.—Of four guinea-pigs receiving such injections with generations 141 and 142 no infections followed. One would naturally conclude that if a small percentage of the animals became infected when inoculated with a 10 tube dose that surely at least in a few instances infection would follow if the material inoculated was tenfold.

Ten Inoculations of One Tube.—Six animals were used for this test and received generations 133 to 139 out of which one revealed the presence of the trypanosome in its blood at the end of 92 days after its first inoculation or 51 days after its last. It lived for 268 days never showing more than 10 parasites per field and that but once. During the greater part of its existence the blood stream was free from organisms and, as a matter of fact, although examined twice a week the trypanosomes were observed but five times.

Ten Inoculations of Ten Tubes.—Animals thus inoculated again showed marked variation as to infectivity with the parasite. One of the eight guinea-pigs which received a multiple of ten culture tube dose developed a very chronic form of Nagana. Trypanosomes were first seen in its blood seven days after the last or 70 days after the first injection and as in the case of the previous guinea-pig the organisms were only observed six times during the trypanosomiasis which lasted for ten days.

SUMMARY.

Nagana manifests itself in three distinct types: the acute; the subacute and the chronic.

The virulence of the trypanosome; its avenue of entrance into

the animal body; the number of parasites injected and the susceptibility of the animal plays an important rôle as to the variety of disease that ensues.

The behavior of the parasite in the animal body is noted by examinations of the blood.

The trypanosome is slightly attenuated when it passes through heterogeneous species.

Cultures of generation one usually infect when incubated from 6 to 11 days while longer incubation renders the culture avirulent.

Cultures of higher generations will infect after 21 days of incubation but they are avirulent after 28 days.

The greater the generation the more marked is the variation in the duration of the disease.

Rats, mice and dogs succumb from the acute type of Nagana when inoculated with trypanosomal blood.

The trypanosome multiplies with marked rapidity and regularity in rats and mice while this is not true in dogs, rabbits and guinea-pigs when infected with the blood type of the parasite.

Rats, mice and dogs suffer from the subacute variety of the disease when inoculated with the *in vitro* strain of the trypanosome.

Rabbits and guinea-pigs develop sub-acute and chronic Nagana when infected with the artificially cultivated parasite.

Rats and mice never develop symptoms of Nagana while dogs, rabbits and guinea-pigs usually do.

Nagana is always fatal to rats, mice, dogs and guinea-pigs while in some cases rabbits may recover, apparently spontaneously.

Rats, mice and dogs are still susceptible to the *in vitro* culture while only a small percentage of the rabbits and guinea-pigs become infected after receiving enormous doses of this parasite.

THE USE OF CLARK AND LUBS INDICATORS FOR THE DETECTION OF ACID PRODUCTION BY THE COLON-TYPHOID GROUP.

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The incorporation, into a medium, of heat resisting indicators is one of the common methods practiced for detecting and determining acid production by bacteria.[1] Clark and Lubs indicators lend themselves especially well to this kind of work because they are heat resisting; they do not inhibit bacterial growth; they resist the action of bacteria; and with a number of them, the virage point is at or near the acid concentration of ordinary stock media. The purpose of the following experiments was to differentiate between the various members of the colon-typhoid group by means of their action on various sugars. No attempt was made to measure the amount of acid produced in each case.

The medium used was a 3 per cent nutrient agar made with .3 per cent Liebig's beef extract, 2 per cent Difco peptone and .5 per cent sodium chloride. The ingredients were mixed and autoclaved at ten pounds for one hour, filtered and the reaction adjusted to slight pink to phenol red (Ph=6.8—7.5). Then the bulk was divided into workable portions and .1 per cent of the desired sugar added to each. This was further divided into three portions and .002 parts of indicator added to each portion. The prepared media was then tubed, sterilized in the autoclave at ten pounds for ten minutes and slanted. Care was taken in slanting to allow for a butt in each tube of at least one inch below the bottom of the slant.[2] After solidification the tubes were ready for inoculation.

The indicators used were brom cresol purple, brom thymol blue, and phenol red. The dyes were all made up in 1 per cent alcoholic solutions which were used for stock solutions. In making dilutions .1 cc. of this 1 per cent stock solution was added to a graduate and media poured into it up to the 50 cc. mark. This gave a dilution of 1 part of dye to 2,000 parts of media. By this method the dye readily mixed with the media and did not require further mixing.

The sugars included dextrose, lactose, sucrose, maltose, raffinose, mannose, dulcitol, xylose, rhamnose, arabinose, levulose, and galactose. All these sugars went into solution very readily if added directly to the hot medium. Some of these are classified as rare sugars and would not be practicable for class room work if used in 1 per cent quantities.

The cultures used were the stock cultures used for laboratory work including *B. coli*, *B. typhosum*, *B. dysenteriae*, *B. paratyphosum* A,

[1] H. R. Baker. Substitution of B.T.B. for Litmus in Routine Laboratory Work. Jour. Bact. Vol. VII. 2.

J. Bronfenbrenner, M. J. Schlesinger and D. Soletsky. On Methods of Isolation and Identification of the Members of the Colon-Typhoid Group of Bacteria. The Study of Bactericidal action of C. R. Indicator. Jour. Bact. Vol. V. 1.

[2] H. J. Conn and G. J. Hucker. The Use of Agar Slants in detecting Fermentation. Jour. Bact. Vol. V. 4.

"Proc. 38th Meeting, 1922 (1923)."

B. paratyphosum B, and *B. enteritidus*. These cultures were carried on stock agar and transferred every twenty-four hours till ready for use.

Inoculations were made in duplicate tubes with a straight platinum wire, inoculating the surface of the slant first and then making a stab in the butt from the bottom of the slant to the bottom of the tube. In reading the tubes the slant and stab were read separately. The stab gave the acid production under anaerobic conditions while the slant gave the acid change under aerobic conditions.

All tubes were incubated at 37° C. for 24 hours.

The following tables give the results obtained.

TABLE 1. 24 Hour Growth. .1 Per cent Arabinose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	yellow	yellow	yellow
	Butt	Color	yellow	green	yellow	yellow	yellow	yellow
		Gas	+	—	—	+ +	+	+ +
B. C. P.	Slant	Color	purple	purple	purple	yellow	yellow	yellow
	Butt	Color	yellow	purple	purple	yellow	yellow	yellow
		Gas	— — —			— — —	— —	— —
P. R.	Slant	Color	pink	pink	pink	yellow	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 2. 24 Hour Growth. .1 Per cent Dextrose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	yellow	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	green	green	yellow	yellow	green
		Gas	—	—		— —	— —	—
B. C. P.	Slant	Color	yellow	yellow	purple	yellow	yellow	yellow
	Butt	Color	red	purple	purple	red	yellow	purple
		Gas	+	—	—	+ +	+ +	+
P. R.	Slant	Color	yellow	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	pink	pink	yellow	pink	pink
		Gas	+	—	—	+ +	+ +	+

TABLE 3. 24 Hour Growth. .1 Per cent Dulcitol.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	green	green	green	green	green
		Gas	—	—	—	—	+	+
B. C P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	pink	yellow	yellow
		Gas	—	—	—	—	+	+

TABLE 4. 24 Hour Growth. .1 Per cent Galactose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B T. B	Slant	Color	green	yellow	yellow	green	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ +
B. C. P.	Slant	Color	purple	yellow	green	purple	yellow	yellow
	Butt	Color	yellow	yellow	purple	red	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ +
P. R.	Slant	Color	pink	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ + +

TABLE 5. 24 Hour Growth. .1 Per cent Lactose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T B.	Slant	Color	yellow	green	green	green	green	green
	Butt	Color	yellow	green	green	green	green	green
		Gas	+ +	—	—	—	—	—
B. C. P.	Slant	Color	yellow	purple	purple	purple	purple	purple
	Butt	Color	yellow	purple	purple	purple	purple	purple
		Gas	+ +	—	—	—	—	—
P R.	Slant	Color	yellow	pink	pink	pink	pink	pink
	Butt	Color	yellow	pink	pink	pink	pink	pink
		Gas	+ +	—	—	—	—	—

TABLE 6. 24 Hour Growth. .1 Per cent Levulose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	yellow	green	yellow	green	green
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
B. C. P.	Slant	Color	purple	yellow	purple	yellow	purple	purple
	Butt	Color	yellow	yellow	purple	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ + +
P. R.	Slant	Color	pink	yellow	pink	yellow	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 7. 24 Hour Growth. .1 Per cent Maltose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	green	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	yellow	yellow	purple	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 8. 24 Hour Growth. .1 Per cent Mannose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	yellow	green	green	green
		Gas	+	—	—	+	+	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	yellow	purple	purple	purple	green
		Gas	+	—	—	+	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	+	—	—	+	+	+

TABLE 9. 24 Hour Growth. .1 Per cent Raffinose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	—	—	—	—	—	—
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	—	—
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	—	—	—	—	—	—

TABLE 10 24 Hour Growth. .1 Per cent Rhamnose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	green	green	yellow	yellow	yellow
		Gas	+	—	—	+	—	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	green	purple	purple	green	purple	yellow
		Gas	+ +	—	—	+ +	—	+ +
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ +	—	—	+	—	+ +

TABLE 11. 24 Hour Growth. .1 Per cent Sucrose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	yellow	lt. green	green	green	green
		Gas	—	—	—	—	—	—
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	—	—
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	—	—	—	—	—	—

TABLE 12. 24 Hour Growth. .1 Per cent Xylose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	green	green	green	yellow	yellow
		Gas	+	—	—	—	+	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	+	—	—	—	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+	—	—	—	+	+

Summarizing these tables it will be found that all three indicators may be used in media for the detection of acid. Phenol red is the most sensitive, as might be expected, then brom thymol blue and finally brom cresol purple. The last two proved very satisfactory and could almost be used interchangeably. The amount of acid produced is the determining factor in each case so that we might expect different results with different indicators. For example, typhoid and dysentery may be differentiated by their action on arabinose with brom thymol blue but not with brom cresol purple. Not enough acid has been produced to bring about a change with brom cresol purple. On the other hand, these same organisms may be differentiated by their action on mannose and galactose with brom cresol purple but not with brom thymol blue. In this case the action has gone too far to be detected with brom thymol blue.

All the sugars used were fermented by one or more organisms. Three of these, dulcitol, raffinose and sucrose were fermented with very little or no gas so that for this purpose they are of little or no use.

Arabinose will divide the group into four parts. Colon, typhoid and dysentery stand out by themselves while para A., para B., and enteritidus remain undifferentiated.

Dextrose is the most easily fermented of all the sugars used. Typhoid, dysentery and enteritidus stand out as distinct individuals while the other three show no difference in their reactions.

Galactose breaks up the group into five parts, para B. and enteritidus in one group and the other four as separate individuals.

Lactose is fermented only by colon.

Levulose gives different reactions for typhoid, dysentery, and para A. while the same reaction is given for colon, para B. and enteritidus.

Maltose is fermented by typhoid but not by dysentery, thereby distinguishing between these two. The others all give like reactions.

Like maltose, mannose will separate typhoid and dysentery but will further divide the remaining four into three groups, colon and enteritidus as separate individuals and the other two undifferentiated.

Rhamnose will distinguish between colon, para A., para B., and enteritidus. Typhoid and dysentery are undifferentiated.

Xylose gives one reaction for colon, para B. and enteritidus and another for typhoid, dysentery and para A.

SOIL BACTERIAL TYPES AND GREEN MANURING.

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In an experiment to determine the effect of calcium carbonate on the biological activities of a soil, it was noted that the addition of green manure seemed materially to alter the equilibrium existing between the bacterial types. This point was deemed of sufficient importance to justify further study and as a result an effort was made to classify the bacterial types developing on agar plates from the treated and untreated soils.

Many investigators have reported the effect of various green manures on the number of bacteria developing in the soil and practically all have found a decided increase following the addition of green manure. However, few investigators have attempted to make a qualitative study of this increase. Hiltner and Stömer[1], in Germany, and Chester[2] and Conn[3], in this country, have carried out the most extensive work in studying and classifying the soil flora. Conn, whose work is far more thorough than any of the others, has classified the soil flora into three main divisions, spore formers, non-spore formers and Actinomycetes. In this same work, Conn reports that the addition of manure to soil disturbs the equilibrium between the bacterial types, greatly stimulating the non-spore forming group. Murray[4], in 1920, reports that the addition of straw to the soil does not appear to stimulate any one type more than the others. Other investigators have reported similar results, the effect varying with the material applied to the soil.

The soil used in this experiment was a black sandy loam, containing a rather high percentage of organic matter and with a lime requirement of about 1,600 pounds calcium carbonate to the acre. Twenty gallon stone jars were filled with ten pounds each of the air dry soil and treated as follows:

Pots 1 and 6 received 500 pounds calcium carbonate per acre.
Pots 2 and 7 received 1,000 pounds calcium carbonate per acre.
Pots 3 and 8 received 2,000 pounds calcium carbonate per acre.
Pots 4 and 9 received 4,000 pounds calcium carbonate per acre.
Pots 5 and 10 received no calcium carbonate.
Pots 11 and 16 received 500 pounds calcium carbonate per acre.
Pots 12 and 17 received 1,000 pounds calcium carbonate per acre.
Pots 13 and 18 received 2,000 pounds calcium carbonate per acre.
Pots 14 and 19 received 4,000 pounds calcium carbonate per acre.
Pots 15 and 20 received no calcium carbonate.

[1] Hiltner, L., and Stormer, K. Studien uber die Bakterienflora des Ackerbodens, mit besonderer Berucksichtigung ihres Verhaltens nach einer Behandlung mit Schwefelkohlenstoff und nach Brache. Kaiserl. Gesundheitsamte, Biol. Abt. Land- u. Forstw. 3, 445-545. 1903.

[2] Chester, F. D. Bacteriological analysis of soils. Del. Agr. Exp. Sta. Bul. 65. 1904.

[3] Conn, H. J. Soil Flora Studies. New York (Geneva) Agr. Exp. Sta., Tech. Bul. 57, 58, 59, 60. 1917.

[4] Murray, T. J. The effect of straw on the biological soil processes. Soil Science, 12, 233-259. 1921.

"Proc. 38th Meeting, 1922 (1923)."

In addition to the above treatment, each pot from 1 to 10 inclusive, received green manure in the form of young rye plants, at the rate of twelve tons per acre.

These pots were placed in the rose house of the Purdue horticultural greenhouses and planted to soybeans. Moisture and temperature conditions were kept at optimum.

Bacterial numbers were determined by plating with standard beef extract agar and incubating fourteen days at room temperature, which was about 20° C.

The bacterial types were studied by sub-culturing on each of the following media:

1. Beef extract agar slants.
2. Beef extract bouillon.
3. Beef extract gelatin stabs.
4. Nitrate reduction solution.
5. Dextrose fermentation tubes.
6. Lactose fermentation tubes.
7. Brom cresol purple milk.

Each culture was also studied microscopically, noting shape, spore formation and motility.

TABLE 1. Bacterial Numbers, Millions per Gram of Soil.

Treatment		Dates of Sampling			
$CaCO_3$ per acre	Green manure per acre	Oct. 19	Nov. 16	Dec. 14	Jan. 11
500 lbs.	12 tons.	1.2	20.0	4.2	7.0
1,000 lbs.	12 tons.	3.2	15.0	3.2	4.2
2,000 lbs.	12 tons.	3.5	10.5	5.7	4.5
4,000 lbs.	12 tons.	1.9	11.2	7.0	4.7
None.	12 tons.	0.8	9.2	3.9	4.7
Average.		2.1	13.2	4.8	5.0
500 lbs.	None.	1.2	8.2	3.1	6.2
1,000 lbs.	None.	2.0	5.0	2.8	5.4
2,000 lbs.	None.	1.4	9.7	2.7	4.6
4,000 lbs.	None.	0.8	7.0	2.6	4.5
None.	None.	1.1	5.0	4.4	5.5
Average.		1.3	7.0	3.1	5.2

Plate counts were made at four different times as shown in Table 1. While the applications of calcium carbonate exerted no appreciable effect on bacterial numbers, the application of green manure greatly increased the total count of bacteria. This is particularly true at the date of the second sampling, four weeks after the experiment was started, when decomposition of the green manure was progressing very

rapidly. At the date of the last sampling, three months after the experiment was started, practically all of the green manure had broken down and the bacterial counts were about the same as in those which had received no green manure.

At the date of the last sampling, ten colonies were picked from the agar plates of each treatment, making one hundred colonies, and were studied as previously described. Care was exercised to make as representative a selection as possible from each set of plates.

TABLE 2. Bacterial Types, as Influenced by $CaCO_3$ and Green Manure.

Treatment		Form			Motility		Sporulation		Gelatin liquefaction	
$CaCO_3$ per acre	Green Manure per acre	Coccus	Rod	Actinomycete	+	—	+	—	+	—
500 lbs.	12 tons	2	6	2	5	5	6	4	9	1
1,000 lbs.	12 tons	3	6	1	5	5	1	9	9	1
2,000 lbs.	12 tons	3	7	0	2	8	2	8	10	0
4,000 lbs.	12 tons	4	6	0	6	4	2	8	7	3
None	12 tons	3	6	1	3	7	5	5	8	2
Total		15	31	4	21	29	16	34	43	7
500 lbs.	None	3	4	3	2	8	5	5	7	3
1,000 lbs.	None	6	4	0	3	7	3	7	7	3
2,000 lbs.	None	3	5	2	5	5	5	5	9	1
4,000 lbs.	None	4	5	1	5	5	5	5	9	1
None	None	7	3	0	3	7	2	8	7	3
Total		23	21	6	18	32	20	30	39	11

Table 2 gives a summary of this work. As in the case of the total bacterial counts, it is seen that the calcium carbonate treatments have exerted no appreciable influence on the bacterial types. However the application of the green manure has caused considerable disturbance in the equilibrium existing between the various bacterial types. The rod forms have increased from 42 per cent of the total to 62 per cent, largely at the expense of the coccus forms. The spore formers have decreased from 40 per cent to 32 per cent, and the gelatin liquefiers have increased from 78 per cent to 86 per cent.

While these results cover only one small angle of a very large problem, they are indicative of what may be accomplished in the future. Each year it is becoming more apparent that our study of the soil flora must be directed toward a more thorough knowledge of the bacterial types and particularly the interrelationships existing between the various groups.

A SIMPLE METHOD OF DETERMINING THE THERMAL DEATH-POINT.

JAMES B. KENDRICK AND MAX W. GARDNER,

Purdue University Agricultural Experiment Station.

Methods of determining the thermal death-point of bacteria have been described by Novy[1], Sternberg[2], Smith[3], and many others. The apparatus ordinarily used is illustrated by Novy and by Smith. The standard procedure consists of a ten-minute exposure of a suspension of the bacteria in a capillary tube or test tube to the temperature desired by immersing the tube in a hot water bath. The methods vary as to the medium and the type of tube used for the suspension, the regulation of the temperature, and the mode of testing the viability of the organisms.

In recent studies of the thermal death-points of certain bacteria causing plant diseases, some modifications of the older methods have been adopted. A heavy suspension of each organism was made in a flask of sterilized distilled water, and equal amounts were then transferred with a sterilized pipette to small sterilized test tubes, one cm. in diameter and seven cm. in length, with walls of fairly uniform thickness. With plant pathogenes there seems to be no especial need of using bouillon or salt solution for these suspensions.

For the water bath a five-gallon wooden candy bucket was placed in a sink under a combination steam and cold water faucet from which a piece of hose led down into the bucket (fig. 1). By turning on either the cold water or the steam and stirring with a stick, the temperature of the water was easily adjusted and controlled. The temperature in such a container is more easily controlled than in the smaller metallic types because of the large volume of water and the relatively low thermal conductivity of the wood. If steam is not available, hot water can be used to raise the temperature since plant pathogenic bacteria are not spore-formers and have low thermal death-points. A. G. Johnson and others working at the University of Wisconsin have made use of a somewhat similar container.

The test tubes containing the organisms were inserted in holes bored in a large, flat, cork float about 15 cm. in diameter so as to project well down into the water. By means of a certified thermometer reading to one-tenth of a degree inserted through a cork into a similar test tube containing water and suspended at the center of the float, the exact temperature of the contents of the tubes could be controlled. The temperature of the water bath was adjusted before the cork float with the test tubes was placed on the surface. After the contents of the tubes had reached the temperature of the bath, a matter usually of about one minute, the float was allowed to remain ten minutes and then was

[1] Novy, Frederick G. Laboratory work in bacteriology. 1-563. 1899. p. 513.

[2] Sternberg, George M. A text-book of bacteriology. 1-708. 1901. p. 154.

[3] Smith, Erwin F. Bacteria in relation to plant diseases. *1*:1-285. 1905. p. 75.

"Proc. 38th Meeting, 1922 (1923)."

17—25870

removed to a jar of cold water so as to cool the tubes at once. The tubes, properly labelled, were then removed to be tested and were replaced by another series of tubes to be exposed to the next higher temperature. Temperatures between 45° and 55°C. were thus tested. The viability of the organisms in each series of heated tubes was tested by means of loop transfers to tubes of slanted agar, and the suspensions

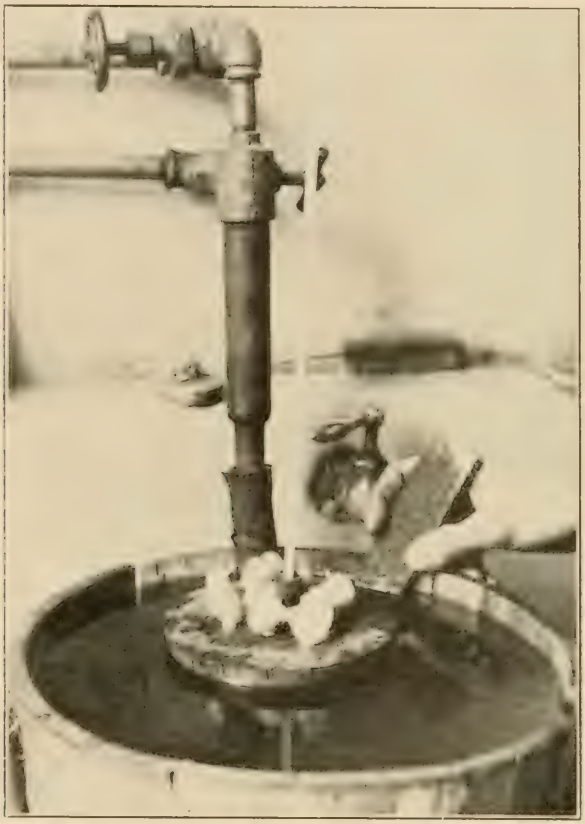


Fig. 1. Thermal death-point apparatus. Large cork float supports thermometer and a number of small test tubes containing the bacterial suspensions. Temperature of water bath adjusted by steam and cold water.

were preserved so that additional transfers might be made from those representing the critical temperatures.

To summarize, the essential phases of this method are the use of water suspensions in small test tubes, the use of a large, wooden container for the water bath in which the temperature is raised by the addition of steam or hot water, the use of a cork float to support the tubes and the thermometer, and the test for viability by making transfers to agar slants.

UNUSUAL STIPULES OF ACER NIGRUM MICHX.

Flora Anderson, Indiana University.

In the autumn of 1921 when the leaves began to fall, some leaves of *Acer nigrum* were noticed that had very prominent stipules. The tree from which these leaves came is just north of Biology Hall on the Indiana University Campus. Since it is 45 to 50 feet to the first limb, no leaves were studied while on the tree. By examining the fallen leaves one could find almost all variations, from those having no noticeable stipules to those having very prominent aecidulated stipules on long slender stalks. The place of attachment of the stipules varied from the base of the petiole to the base of the blade (figs. 4 to 9). The blade of the stipule was either straight or aecidulated. Figures 3 and 4 show both types on the same leaf.

Britton[1] in his description of *Acer nigrum* says . . ; "the leaf-stalks are also hairy, at least when young, and are expanded at the base, often bearing stipules which are sometimes 3 or 4 cm. long". On a single tree one may find leaves with the petioles scarcely expanded at the base, and other leaves with very large, conspicuous stipules—the blade of the stipule sometimes 6 or 7 cm. long—on slender stalks (fig. 13). Then there may be found all gradations between these. Hough[2] says . . ; "petioles stout and generally bearing stipules at the enlarged base". He figures a branch and calls attention to "the presence of a few small stipules. They are occasionally much larger". Deam[3] in his description of the species says . . . "petioles usually 3-15 cm. long which are more or less swollen at the base and by maturity develop a scale-like appendage on each side of the petiole at the base—especially on each of the terminal pair of leaves, sometimes with foliar stipules which are 2-3 cm. long on stalks of equal length". His plate 114 is a photograph of a branch of *Acer nigrum* which shows two leaves with unusual stipules—one at the base of the petiole, the other near the blade of the leaf. Gray[4] mentions; "stipules often conspicuous" and again[5], "Stipules large, early deciduous." Quite a number of authors make no mention of stipules in their description of *Acer nigrum.*

Since the taxonomist had made no special note of these unusual stipules, the writer thought they might be "early deciduous", and in the spring of 1922 began to examine *Acer nigrum* trees for leaves with stipules of unusual character. During the spring and summer, trees on the Indiana University Campus and on the streets of Bloomington were observed. On almost all of these trees were found leaves of different types, varying from those with practically no stipules to those with large foliar aecidulated stipules on slender stalks. The point of attachment of

[1] Britton, Nathaniel Lord. North American Trees. p. 651. 1908.

[2] Hough, Romeyn Beck. Handbook of the Trees of the Northern United States and Canada. pp. 326-327. Fig. 382. 1907.

[3] Deam, Chas. C. Trees of Indiana. p. 246. pl. 114. 1921.

[4] Gray, Asa. New Manual of Botany. 7th Ed. p. 558. 1908.

[5] Gray, Asa. Field, Forest and Garden Botany. Revised. p. 112. 1895.

"Proc. 38th Meeting, 1922 (1923)."

Figs. 1-14. Types of stipules of *Acer nigrum Michx.* x ½.

these stalks to the petiole ranged from the base of the petiole to the base of the blade of the leaf. Observations made on trees in the state park at Spencer, Indiana, and on street trees in Crawfordsville and Ladoga, Indiana, revealed the same conditions. Neither the age nor the vigor of the tree seemed to make any difference in the relative number or kind of stipules produced.

When one sees a leaf with stipules like those in figures 1 and 2, there seems to be nothing unusual; but on observing one with stipules like those in figures 3, 5 and 11 where one sees apparently the normal stipule plus something else, there is a question. Are these structures a part of the so called "normal stipule", or are they structures originating in the axils of the stipules? Some leaves would seem to indicate that they were simply enlargements of the normal stipule (fig. 12). But other leaves show the slender stalks of the unusual stipules coming from the axils of the normal stipules. Even when these stalks come apparently from different places on the petiole, they can usually be traced by a ridge on the petiole back to the axil of the normal stipule (figs. 10 and 11). Sometimes three of these stipules may be found on one leaf (fig. 14), or one may fork as is shown in figures 10 and 13. Or, this stipule may be sessile at the base of the leaf blade, appearing at first glance as a lobe of the leaf (fig. 9). The blade of the stipule may be very simple and entire as is seen in figure 4, A; or it may be aecidulated and variously lobed as is shown in figure 6. The lobes of the stipule are frequently similar to those of the leaf blade.

By late summer, a few of these stipules had fallen, leaving only a slight scar. As far as the writer could ascertain, only a very few of these unusual stipules might be classified as "early deciduous". A great many of the leaves examined late in the autumn still retained their stipules. There seemed to be no tendency, except in a few instances for the stipules to be shed before the leaves fell.

In conclusion it might be said that all the trees examined had at least a few leaves with unusual stipules, but some trees showed a much larger proportion of stipulate leaves than others. Whether or not there is something inherent in the tree that causes it to produce these unusual stipules is not known. Observations of certain trees of opposite tendencies made from year to year, and seedlings from these trees might in a measure help to solve the problem. But before a definite conclusion can be formulated, it seems necessary to study a large number of trees of different localities, and also to study the origin of these unusual stipules morphologically.

DEVELOPMENT OF SPOROGENOUS TISSUE IN THE FOOT OF THE SPOROPHYTE OF PORELLA NAVICULARIS.

FLORA ANDERSON, Indiana University.

From fresh material of *Porella navicularis* sent from Corvallis, Oregon, in the fall of 1920, quite a number of young sporophytes were

fixed in one per cent chromo-acetic acid and later sectioned for class use. Whole buds were used for the sectioning, the sections being longitudinal and 15μ in thickness. Modified triple was used for staining the sections.

Fig. 1. Longitudinal section of bud of Porella showing unusual development of sporogenous tissue. x 45. A, sporangium; W, sporangium wall; S, stalk of sporophyte; F, foot of sporophyte.

On examining the slides, one was noticed which was different from the others. The gametophyte tissue surrounding the young sporophyte was apparently normal, but the sporogenous tissue had grown so vigorously that it occupied nearly the whole of the sporophyte. The cells of the foot, stalk and sporangium wall were shrunken and crowded out of place—the spores and elaters occupying most of the foot and stalk as well as the sporangium (fig. 1).

PLANTS NEW TO INDIANA, XI.

CHAS. C. DEAM, Bluffton, Indiana.

Duplicates of the species reported in this paper, excepting *Crotalaria sagittalis*, have been deposited in the Gray Herbarium or in the National Herbarium. The grasses were determined by Agnes Chase. The determination of the remaining species was either made or checked at the Gray Herbarium.

Isoetes engelmanni A. Br.

Norma E. Pfeiffer in her monograph of the Isoetaceae, published in the Annals of the Missouri Botanical Gardens, Vol. 9:206:1922, says that my number 22385 which was reported as *Isoetes braunii* belongs to this species. In the same publication she refers my number 20467, reported as *Isoetes foveolata*, to the same species.

Eragrostis hirsuta (Michx.) Nees.

Posey County, Aug. 20, 1922. No. 37704. In clayey soil along the roadside on the south side of Half Moon pond about nine miles southwest of Mt. Vernon.

Melica nitens Nuttall.

Clark County, May 7, 1922. No. 35456. Found growing in full sunlight on the narrow ledges at the top of a cliff along the Ohio River about a half mile east of the mouth of Fourteen-mile Creek. The cliff at this point faces to the south and is about 250 feet high.

Harrison County, May 11, 1922. No. 35548. In partial shade on the narrow ledges and in the talus of the cliff of the Ohio River about two miles southwest of Laconia.

Cyperus pseudovegetus Steud.

Posey County, August 19, 1922. No. 37685. Common in a roadside ditch three miles west of Hovey, or about seven miles southwest of Mt. Vernon.

Juncus dichotomus Ell.

Laporte County, June 26, 1922. No. 36704. In a prairie habitat along the railroad about one mile south of Wanatah. Rare here. This species was reported for Randolph County by Phinney but since no specimen exists, we have no means of checking the determination. A specimen is in the Gray Herbarium collected by Schneck which was determined to be this species. H. H. Bartlett and C. A. Weatherby have examined this specimen and both report it to be an immature specimen of *Juncus tenuis*. Smith reported Bartlett's examination in Proc. Ind. Acad. Sci. 1905:156:1906.

Carex annectans Bicknell.

Crawford County, May 28, 1919. No. 27710. In a low flat woods about three miles northwest of Leavenworth.

St. Joseph County, June 8, 1922. No. 36366. In an old marsh bed about five miles west of South Bend.

Silene chloranthe (Willd.) Ehrh.

Monroe County, Sept. 17, 1922. No. 37989. Collected by myself and Paul Weatherwax in sand ballast along the Monon Railroad about

one and a half miles northwest of Harrodsburg. Corolla yellowish. Frequent here for a distance of about 25 feet.

Crotalaria sagittalis Linnaeus.

Perry County, Aug. 6, 1922. No. 36502. In an abandoned field near the crest of a ridge about two and a half miles east of Oriole. Associated with a thick stand of *Cassia chamaecrista*. First discovered by Mrs. Chas. C. Deam. After a search over an acre or more we found only two specimens. This species was reported by Schneck as occurring in the lower Wabash Valley but he cited no definite locality. Indiana is included in the range of this species in the Gray Manual, but the Gray Herbarium does not contain a specimen from Indiana.

Ludwigia glandulosa Walt.

Posey County, Aug. 20, 1922. No. 37699. In an open swamp in a woods in the southwest corner of Section 32 of Point Township. Closely associated with *Cephalanthus occidentalis*, *Styrax americana*, *Lobelia cardinalis*, *Ludwigia polycarpa* and other plants about four feet high.

Chaerophyllum procumbens, variety *shortii* T. & G..

Clark County, May 7, 1922. No. 35477. Alluvial bank of the Ohio River about three-fourths of a mile above the mouth of Fourteen-mile Creek. *C. procumbens* was found about one-fourth mile from the variety and was just beginning to mature its fruit while at the same time the variety was in full fruit, apparently about ten days difference.

Lappula redowskii, variety *occidentalis* (Wats.) Rydb.

Porter County, June 25, 1922. No. 36680. Frequent along the right of way of the Pere Marquette Railroad about five miles southwest of Michigan City.

Mentha cardiaca Gerarde.

Spencer County, Aug. 9, 1922. Several specimens were found in a pasture field about two miles north of Lamar. It grew in a hard clay soil in a low flat field.

Plantago purshii R. & S.

Newton County, June 11, 1922. No. 36502. On a cleared black oak ridge just west of Conrad. Growing in almost pure sand with *Koeleria cristata*, *Stipa spartea*, *Carex brevior*, *Lithospermum gmelini*, *Panicum pseudopubescens*, *Panicum scribnerianum* and *Panicum perlongum*. This is the first definite record for Indiana, although both Gray's Manual and Britton and Brown's Ill. Flora ed. 2, credit Indiana with it. There is no specimen of this species from Indiana in the Gray Herbarium or the New York Botanical Gardens.

Houstonia angustifolia Michx.

Harrison County, Aug. 3, 1922. No. 37238. Growing in very shallow soil in an exposed place on the top of the limestone bluff of the Ohio River about one and a half miles northeast of Davidson.

Sonchus uliginosus Bieb.

Noble County, July 11, 1922. No. 36832. A colony in dry soil in blue grass sod on the west side of the road three and a half miles south of Albion.

THE EFFECT OF PRESSURE ON GROWTH.

F. M. Andrews, Indiana University.

Numerous experiments have been carried out to show the effect of air pressure on plants. Among these may be mentioned the work of Bert[1]. Later Wieler[2] studied the question of reduced pressure of oxygen and Jentz[3] of increased oxygen pressure. Some of these facts are also set forth by Pfeffer[4]. Czapek[5] also points out a number of interesting researches on this subject.

The points to be mentioned briefly here, however, refer to the effect of water pressure on plant growth. That the roots of plants grow when submerged in water is common knowledge but when the pressure of the water is increased there is an effect which varies with the intensity of the pressure. The writer noticed long ago that centrifuging caused the roots of corn seedlings to become translucent due to the fact that part of the water surrounding the seedlings was forced into the roots. For example, the roots of the control or uncentrifuged seedlings retained their normal color in water, but those which were centrifuged and subjected to a force equivalent to a column of water 30 meters high, became clear in 15 minutes.

The combined action of centrifugal force and water pressure was observed in another experiment. In this case control seedlings of corn which were 3 cm. long grew 2 mm. in water in four hours at 24°C. The centrifuged corn seedlings of the same size and under exactly the same conditions grew only 1 mm. in four hours, under a water pressure of 30 meters. Numerous other experiments performed in this way using both smaller and greater amounts of water pressure verified these results.

In another series of experiments the seedlings of corn were subjected to water pressure without the action of centrifugal force. Corn seedlings 3 cm. long and used as controls grew, on the average, 2.1 mm. in four hours at 24°C. in this set of experiments. The corn seedlings 3 cm. long and which were subjected to a pressure of 30 meters of water grew 1.5 mm. in four hours at 24°C. The effect of pressure in this case which was equal to a column of water 30 meters in height amounted, therefore, to a growth check of .6 mm. in four hours.

A third series of experiments was performed to test out the effect of extremely high pressures on the growth of seedlings. Corn seedlings 2 cm. long were exposed to water pressure of 50 atmospheres at a favorable temperature for five minutes. At the end of this time the roots so treated were clear. These seedlings and other corn seedlings 2 cm. long used as controls were planted in sawdust. In 24 hours the

[1] Bert, P. Compt. rend. 1877 Tome 84 p. 1130.

[2] Wieler, A. Die Beeinflussung des Wachsens durch verminderte Partiärpressung des Sauerstoffs. Unters. a. d. Bot. Institut z. Tübingen 1833 Bd. I. p. 189.

[3] Jentys, Stefan. Ueber den Einfluss hoher Sauerstoffpressung auf das Wachstum der Pflanzen. Unter. a. d. Bot. Institut z. Tübingen 1886 Bd. II p. 419.

[4] Pfeffer, W. Pflanzenphysiologie Zweite Auf. Bd. I. p. 548; Bd. II p. 133-134.

[5] Czapek, F. Biochemie der Pflanzen 1905 Bd. II, p. 396 and the literature quoted in the above references.

"Proc. 38th Meeting, 1922 (1923)."

controls were 4 cm. long while the seedlings from the pressure test were 3.6 cm. long. They continued to show some difference for three days after which time all were of the same average size and vigor.

Corn seedlings 2 cm. long were subjected in the second experiment to 100 atmospheres pressure under the same conditions. After 24 hours the controls averaged 4 cm. in length while the experimental seedlings were 3.2 cm. long on the average. In five days all were equal in size and vigor. Other experiments showed these seedlings to have become clear in three minutes.

In a third experiment corn seedlings 2 cm. long were placed in a water pressure of 200 atmospheres for five minutes. They became clear in about two minutes. When planted the controls averaged 4.2 cm. while the experimental seedlings averaged 2.8 cm. In seven days all seedlings averaged the same size and were equal in vigor.

In a fourth series of experiments corn seedlings 2 cm. long were placed in a water pressure of 400 atmospheres for five minutes. Experiments showed that they became clear on the average in one-fourth of a minute. In 24 hours the controls averaged 4.1 cm. in length while the test plants were 2.5 cm. long. In 12 days all seedlings were equally large and vigorous.

Finally corn seedlings 2 cm. long were placed in a water pressure of 600 atmospheres. As nearly as could be determined they became clear on the average in 10 seconds. In 24 hours the controls averaged 4.3 cm. and the test plants averaged 2.3 cm. in length. In 18 days all seedlings were of equal size and vigor. The high pressure recorded in the last five experiments was obtained by means of a Geneva Society high pressure pump which will produce pressures up to 1000 atmospheres. Melsens[6] states that yeast will live under a pressure of 8000 atmospheres. Corn seedlings can withstand great pressure and recover in a comparatively short time. It is to be noticed, however, that the time of recovery is delayed according to the intensity of the pressure.

[6] Melsens. Comp. rend. 1870. Bd. 70 p. 831.

CHLOROPLASTS OF *MARTYNIA FRAGANS.*

F. M. Andrews, Indiana University.

Martynia shows an interesting arrangement of the chloroplasts in the trichomes on the stems and elsewhere. This arrangement together with the rate of movement of the chloroplasts form the chief points of this paper, which for the plant above mentioned, have not heretofore been determined. Senn[1] has studied a large number of other plants as regards their chloroplasts. Stahl[2] also has investigated the subject and Noll[3] has studied the movements of the chloroplasts in *Schistostega osmundacea.*

The trichomes of Martynia vary in length, some being more than two mm. long. Those under consideration terminate in an enlarged end. Viewed collectively they impart to the plant a velvety appearance, and the rather large clear drop of viscous liquid, often seen on their

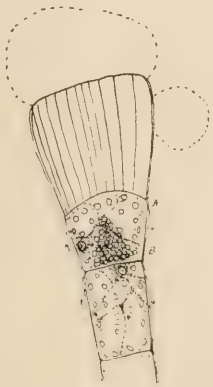


Fig. 1. Top of trichome of Martynia.

ends, gives to the plant its clamminess (fig. 1). When magnified only five times and observed laterally the transverse walls of many of the larger trichomes can barely be seen since they consist of a single roll of cells. When magnified five times, the presence of the chlorophyll color may be discerned in the region occupied by the two cells just under the end of the trichome. The microscope shows few chlorophyll granules near the base of the trichome. This is easily observable since the cell walls are thin. The interior of the cell is clear except for the chloroplasts. Protoplasmic movements are visible in various directions as indicated by the arrows in figure 1. The trichomes near the tip of the plant where the light is more favorable possess more chloroplasts.

The chief interest centers in the first terminal chlorophyll-bearing cell (fig. 1). Under one set of light conditions the chloroplasts collect

[1] Senn, Gustav. Die Gestalts und Lageveränderung des Pflanzen-Chromatophoren 1908 and literature there quoted.

[2] Stahl, E. Botanische Zeitung 1880 Bd. 83. pp. 297, 321, 345, 361, 377, 393, 409.

[3] Noll, F. Arbeiten des Botanischen Instituts in Würzburg Bd. 3 pp. 477-488.

at the end of the cell marked B, and under other conditions collect at A. The speed, however, with which these and other movements of the chloroplasts takes place is unusual. Senn[1] has shown that the chloroplasts of Funaria under optimal conditions of light move 4μ in eight minutes. The chloroplasts of the trichomes of Martynia, however, under optimal conditions of light move much faster, in fact, namely, 21μ in seven minutes. In the cells observed it required from 37 to 43 minutes under fairly constant optimal light and temperature conditions for the chloroplasts to traverse the cell. This shifting of the chloroplasts leads to the well known change in chlorophyll color of certain plant organs.

QUANTITATIVE ESTIMATION OF AERATION IN LEAVES.

F. M. Andrews, Indiana University.

It has been known for a long time that air can be made to move back and forth through the stomata of leaves and that this can be accomplished in some plants with only a slight force[1]. Some plants allow the passage of air in this way with marked ease and among them may be mentioned the following: Nymphaea, Funkia, *Calla aethiopica*, *Arum maculatum*, and Rumex[2]. To these I might add *Myriophyllum proserpinacoides* which is cultivated in aquaria.

A quantitative estimation of the amount of air which can be passed through leaves has not been made. The first investigator to see air pass in this way from stomata was Raffeneau Delille[3]. Since that time Sachs[4] and others have worked on the problem.

I have experimented with a number of plants in this respect. One of these was *Nymphaea odorata* which was an especially favorable object. Air was easily caused to pass through the leaf in bubbles with a vacuum of 12 mm. of mercury, which is less force than was required by the specimens of the same genus mentioned by Pfeffer[5]. The same thing was accomplished by arranging the petiole under a cylinder of water filled to a height of about 30 cm. and then inverted over a dish of water as indicated by Jost[6]. The air in this case issued from the petiole with great rapidity and in large quantity. The stream of bubbles can easily be made visible to a large audience by proper arrangement of a lens of correct magnifying power. The volume of air thus passed through the leaf of *Nymphaea odorata* was 10 cc. in 16 seconds. One thing must be borne in mind with *N. odorata* and that is the status of the leaf for

[1] Senn. l. c. p. 320.

[1] Pfeffer, W. Pflanzenphysiologie Zweite Auf. 1894 Bd. 1 pp. 178-179 and literature there quoted.

[2] Pfeffer, W. l. c. p. 179.

[3] Raffeneau, Delille. Annales d. Scien. natur. 1841. XIV 328. Quoted by Von Hohnel Jahr. f. wiss. Bot. 1879. Bd. 12 p. 48. See other literature there quoted.

[4] Sachs, J. Ueber die Bewegung der Gase in den Pflanzen. Handbuch der Experimental-Physiologie des Pflanze 1865 pp. 243-262.

[5] Pfeffer, W. l. c.

[6] Jost, L. Lehrbuch der Botanik. 15 Auf. 1921 p. 216.

an air passage. If the petiole of such a leaf is arranged as above indicated the air may not issue from the cut end of the petiole for a very long time, or not at all under slight vacuum. At times as much as 30 minutes elapse under slight vacuum before the air passage begins. When, however, it has once begun it continues with great rapidity until the expelling force is removed. When the passage of air does not begin at once the suction should be increased by lengthening the mercury or water column till the flow of bubbles commences. The force employed may then be decreased if desired to the minimum amount that will sustain a continuous stream of air bubbles. The stream of air bubbles will cease as soon as the leaf is immersed and will commence again as soon as it is restored to the air. This proves that the failure of air to pass at first under slight vacuum was not caused by the stomata being blocked with water, but was due to other causes. Large quantities of air issued even under the small vacuum. The leaves tested were of medium size, being about 12 cm. wide and 14 cm. long, and were vigorous in every respect.

Myriophyllum proserpinacoides allows air to pass with ease but not quite so easily as *Nymphaea odorata*. For example, a vacuum of 16 mm. of mercury was required to cause the air to flow through this plant from the leaves. The volume of air passed through was much less than for *N. odorata*. For example, it required five minutes for 1 cc. of air to emerge from the stem. The combined amount of surface of many leaves of *M. proserpinacoides* is much smaller than a single one of *N. odorata* so that the difference per unit area is not so great as might be expected.

The genus Rumex offers a very interesting land type of this function in contradistinction to the two foregoing aquatic types. The species experimented with was *R. obtusifolius*. Leaves 10 cm. wide and 16 cm. long were used. In these leaves a vacuum of only 28 mm. of mercury was required to cause the air to flow through the stomata and out of the petiole. Quantitatively the amount of air passed through the leaf was much less than in either of the first two plants discussed. At a minimum vacuum of 28 mm. of mercury only 1 cc. of air passed through the petiole in 17 minutes. As in the case of the first two plants, this flow instantly ceased when the leaf was submerged in water but began again when restored to the air. This, however, did not occur quite as quickly in the case of *R. obtusifolius*. The stomata of the leaves of *R. obtusifolius* are large. If one knows the size of the stomata and the volume of the air which issues, the number of stomata per unit area may therefore be easily calculated. If the leaves of these plants are attached directly through rubber stoppers or in tubes the amount of vacuum necessary to bring about the desired result is so small that the union may easily be made air tight by the use of plastilina. While in most plants the interchange of air is effected with much greater difficulty, the quantitative estimations here given for the three plants above mentioned show clearly the decided capabilities of certain plants in this respect. *Rumex obtusifolius* and *Myriophyllum proserpinacoides* can be used as excellent demonstration material before an audience. When *R. obtusifolius* was connected with a 1200 cc. flask on which a vacuum of 20 cm. of mercury

was placed the air was caused to stream inwardly through the stomata and out of the petiole continuously for two and one-half hours without renewing the vacuum.

AN UNUSUAL IRIS.

F. M. Andrews, Indiana University.

Two years ago I transplanted the rhizomes of some Irises to a rather damp location. All were the common large blue flag (*Iris versicolor*). The rhizomes sent up the aerial parts and produced 60 flowers of which three were unusually large, being 12 cm. long and nearly as broad, whereas the usual length is 5 to 8 cm. This represents an increase in size of at least one third. The inner segments were pure yellow and only about one-half the length and breadth of the sepals. Ordinarily the flowers of this species are colored yellow, green or white toward the center[1]. The petals were marked in places by purple dots which recalled to a degree the appearance of the flower of *Belamcanda chinensis*. The rhizomes from which these three flowers above mentioned came bore in every other instance blue flowers of the normal size and color.

SECOND BLOOMING OF SNOWBALL BUSH IN THE SAME YEAR.

F. M. Andrews, Indiana University.

On September 4, 1922, the writer noticed an account of a snowball bush which was in bloom for the second time that year. The plant was at the home of H. P. Carpenter of Elwood, Indiana, who, upon request, very kindly forwarded to me a cluster of the flowers and a branch with some leaves so that a study of the specimen could be made. He wrote that "the first time it was in bloom the bush was literally covered with blossoms, but the last time there were only a few, probably a dozen or more". This agrees with some other plants which have bloomed more than once in a season and to which the author has previously made reference[1]. The second blooming was conspicuous in specimens that were more or less diseased, due apparently to the attack of fungi or other injury. Injury may easily be caused by the attacks also of insects of various kinds and the snowball is at times injured to a high degree by this means.

The characteristics of the specimens at hand agree with *Viburnum opulus* or what is sometimes called the guelder rose or snowball. The flowers are white and are borne in a long peduncled cyme about 6 cm. in diameter. This however, falls far short of the usual size of the normal cyme clusters of *V. opulus* which often average 12 cm. in diameter.

[1] Gray, Asa. New Manual of Botany Seventh Edition.

[1] Andrews, F. M. Proceedings of the Indiana Academy of Science 1905, pp. 187-188; 1909, pp. 373-374; 1911, pp. 279-281.

Therefore, it is to be observed, that, during the second anthesis the number of clusters was greatly reduced, and the size of the individual cymes was much less.

Ordinarily *V. opulus* blooms in the early summer so that in this case about two months or more must have elapsed between the first and the second anthesis. Certain other species of this genus may be "forced" to bloom by the addition of heat during cold weather.

Regarding the second blooming of plants in the same season we have various suggestions as to its cause. If branches of certain plants are allowed to project into a warm greenhouse during the winter, these branches will develop transpiring leaves although the remainder of the plant may be outside in low temperature. This shows that water is still absorbed by the roots and passed through the stem.[2] Some plants under such conditions are unable to absorb water from a frozen soil and hence wilt.[2] Kerner[3] observed that a root of a Clematis plant growing in cold air and frozen developed leafy stems when a branch was conducted into a hothouse. The food substances made in the summer were available for use as soon as deposited[2]. He says further: "The same must indeed be the case in those plants which bloom normally in the spring, but yet often in years characterized by particularly mild autumns, burst open in October, the buds destined for the next spring thus sending out fresh leafy shoots and blossems twice in the same year—for example,—many apple and horse chestnuts, violets and strawberries, many primulas, gentians and anemones." So in the case of the second blooming of the snowball here discussed, a rather high temperature might have influenced the plant to renew fruiting activity. Reference to the local weather bureau records shows that the temperature ran high during the second blooming of this plant. This influence of temperature on the second blooming of plants is upheld by an account by Darwin and Shrubbs entitled "Records of Autumnal or Second Flowerings of Plants". They enumerate 75 such plants in England and further state: "It can hardly be doubted that these second flowerings are connected with relatively high temperatures"[4].

Recently an account of an eight to nine year old cherry tree near Bloomington, in full bloom for the second time in the same season, came to the notice of the writer. Here again the high temperature prevailing during the second blooming of this tree indicates strongly the close connection between high temperature and the second seasonal blooming of plants.

[2] Pfeffer, W. Physiology of Plants. English Edition Vol. 1, p. 231.
[3] Kerner, H. and Oliver, T. W. English Edition. Vol. 1, p. 564.
[4] Darwin, Frances and Shrubbs, A. Records of Autumnal or Second Flowerings of Plants. The New Phytologist 1922. Vol. 21, p. 48.

THE CONVOLVULACEAE OF INDIANA.

TRUMAN G. YUNCKER, DePauw University.

The family Convolvulaceae is represented in Indiana by the genera Quamoclit, Ipomoea, Convolvulus and Cuscuta. The eight species of Cuscuta known to occur in our State have been discussed by the writer in recent papers[1] presented to this Academy. It is proposed, in the present paper, to present the species of the other three genera occurring in Indiana and indicate their distribution and prevalence. Eleven species may be recognized, one in the genus Quamoclit, four in the genus Ipomoea, and six in the genus Convolvulus. All of these eleven species present fairly definite and constant characters by which they may be identified, with the possible exception of *Convolvulus sepium* and its close relative *C. fraterniflorus*. A study of a larger number of collections of these two species gathered over a wider range may show the inadvisability of maintaining them as separate species. Most of the species show considerable variation in the shape of the leaves. In *Ipomoea lacunosa*, for example, one may discover leaves of two or three distinctly different shapes even on the same plant. Sketches are presented showing this variation in leaf form and size in the different species.

All of the specimens that could be obtained were studied and compared. Mr. C. C. Deam's extensive collection was generously placed at the writer's disposal and provided the largest number of specimens. All collections are listed and the county in which they were obtained is indicated. No collections or localities are included where the specimens were not seen by the writer.

KEY.

Corolla tubular, not expanded at the base, limb salverform; stamens and style exserted; flowers not subtended by bracts ..... 1. *Quamoclit coccinea.*

Corolla mostly funnelform, stamens and styles not exserted

Stigmas 2 or 3, grouped into a rounded, frequently papillate, knob; flowers not subtended by bracts ..... (Genus Ipomoea).

Stems, petioles and peduncles retrorsely hairy

Sepals mostly long, attenuate-caudate, tips spreading..... 2. *Ipomoea hederacea.*

Sepals ovate-oblong to lanceolate. 3. *Ipomoea purpurea.*

[1] Notes on our Indiana dodders. Proc. Ind. Acad. Sci. for 1919. pp. 157-163.
A Species of Cuscuta not hitherto reported from Indiana. Proc. Ind. Acad. Sci. for 1920. p. 229.

"Proc. 38th Meeting, 1922 (1923)."

18—25870

Stems, etc., not retrorsely hairy
Sepals broadly ovate or oblong, smooth ..... 4. *Ipomoea pandurata.*
Sepals ovate to lance-ovate or oblong, pointed, hairy..... 5. *Ipomoea lacunosa.*
Stigmas 2, oval or filiform, elongated; 2 bracts closely subtending each flower (they are some little distance from the flower in *C. arvensis*) ..... (Genus Convolvulus).
Petioles mostly less than one-fourth as long as the blade; plant short, upright, hairy..... 6. *Convolvulus spithamaeus.*
Petioles mostly more than one-fourth as long as the blade; plant trailing or twining
Flowers double ..... 7. *Convolvulus japonicus.*
Flowers single
Bracts surrounding and enclosing the calyx
Leaves smooth or, infrequently, hairy; peduncles mostly longer than the petioles. 8. *Convolvulus sepium.*
Leaves hairy
Leaves moderately hairy, hastate, peduncles not exceeding the petioles ..... 9. *Convolvulus fraterniflorus.*
Leaves densely hairy, basal lobes rounded, peduncles exceeding the petioles ...10. *Convolvulus repens.*
Bracts small and at some distance from the flower.....11. *Convolvulus arvensis.*

1. QUAMOCLIT COCCINEA.

Figs. 1 & 2.

Quamoclit coccinea Moench, Meth. 453. 1794.

Plant smooth or slightly hairy at the nodes; leaves cordate, entire, or, infrequently, angled; peduncles one- to several-flowered and longer than the petioles; sepals bearing a prominent, dorsal projection; stamens and styles exserted.

Along roadsides and in cultivated fields.

Specimens examined:—Gibson Co. (Deam *18,306*); Harrison Co. (Deam *18,735*); Jefferson Co. (Coulter in 1874); Lawrence Co. (Deam *18,443*); Putnam Co. (Yuncker *1,353*); Sullivan Co. (Deam *32,922*); Warrick Co. (Mrs. Deam *33,117*).

2. IPOMOEA HEDERACEA.

Figs. 3 & 4.

Ipomoea hederacea Jacq. Icon. Rar. pl. 36. 1781.

Plants hairy, with the hairs on the stems, petioles and peduncles pointing downward; leaves three-lobed; sepals long, attenuate-caudate, tips curving, densely hairy at the expanded base.

Rather common in cultivated fields and waste places.

Specimens examined:—Clark Co. (Deam *5,433*); Crawford Co. (Deam in 1899); Franklin Co. (Deam in 1903); Greene Co. (Deam *37,711*); Hancock Co. (Deam *37,841*); Jefferson Co. (Coulter in 1875); Marion Co. (Deam *7,350*); Morgan Co. (Deam *2,692*); Perry Co. (Deam *37,419*); Posey Co. (Deam *37,698*); Putnam Co. (McDougall in 1888 and in 1889; Yuncker *1,355*); Vigo Co. (Deam *32,900*).

3. IPOMOEA PURPUREA.

Figs 5 & 6.

Ipomoea purpurea (L.) Lam. Tabl. Encycl. 1:466. 1791.

Plants hairy, with the hairs on the stems, petioles and peduncles turned downward; leaves cordate, or, infrequently, angled; sepals ovate or oblong, acute, densely hairy at the base.

In cultivated fields, along roadsides and in waste places generally.

Specimens examined:—Putnam Co. (Bates in 1911; Grimes 778; Yuncker *1,354*); Shelby Co. (Deam *19,082*); Spencer Co. (Deam *37,492*).

Specimens collected in Kosciusko and Wells Counties by Deam (Deam *1,498* and *5,296*), have sepals similar to those of *I. purpurea*, but the leaves are lobed and in all respects are similar to those of *I. hederacea*, while a specimen collected in Putnam County showed the contrary condition, i.e., it had the calyx lobes of *I. hederacea* and the leaves of *I. purpurea*. These combinations of characters suggest a cross between these two closely related species. So far as I have been able to find, no mention has been made before of this combination of characters.

4. IPOMOEA PANDURATA.

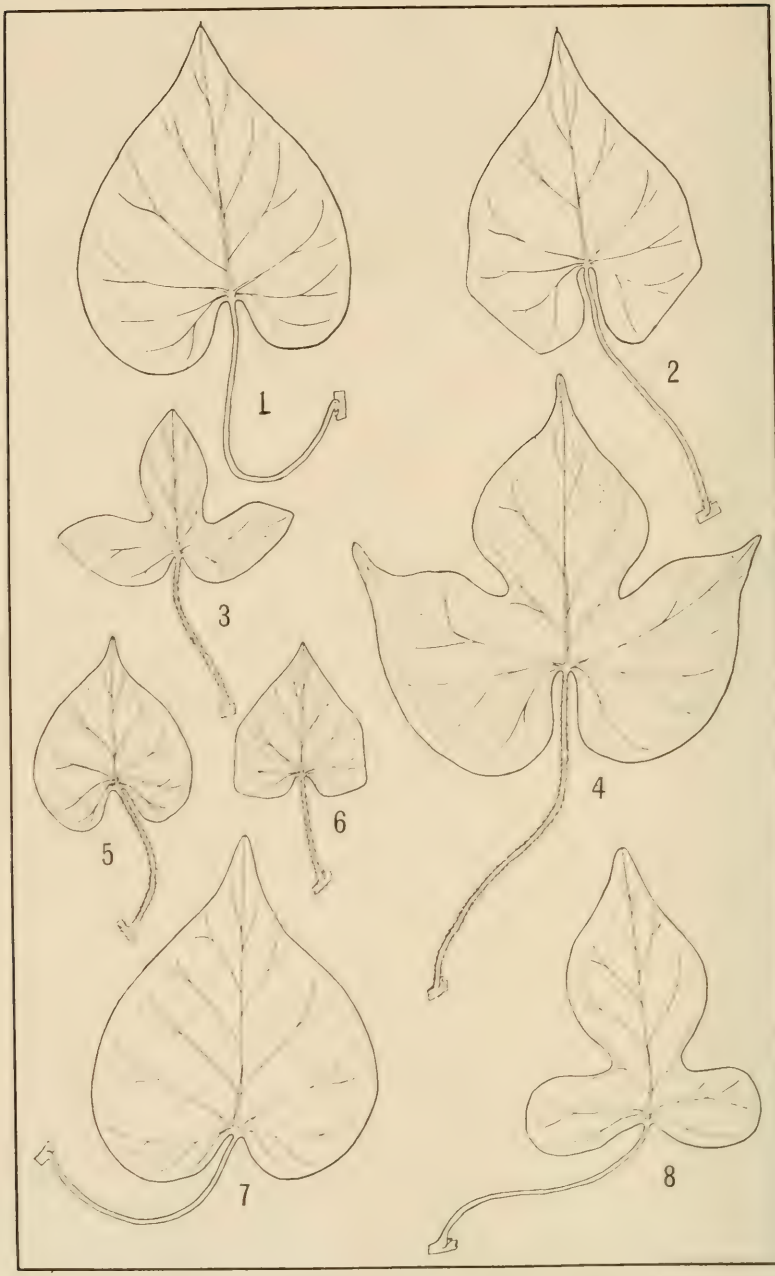
Figs. 7 & 8.

Ipomoea pandurata (L.) G.F.W.Mey. Prim.Fl.Esseq. 100. 1818.

Plant robust, smooth or, rarely, hairy; leaves ovate or, infrequently, constricted at the middle forming basal lobes; peduncles mostly longer than the petioles, 1-6 flowered.

Common in dry soil in waste places.

Specimens examined:—Allen Co. (Deam *1,358*); Blackford Co. (Deam *1,181*); Clark Co. (Deam *7,039*); Daviess Co. (Deam *25,643*); Dubois Co. (Deam *11,589*); Hamilton Co. (Mrs. Deam *12,151*); Harrison Co. (Deam *37,212*); Jefferson Co. (Coulter in 1875); Jennings Co. (Deam *37,021*); Knox Co. (Deam *17,006; 37,721*); Perry Co. (Deam *37,392A; 37,418*); Posey Co. (Deam *37,711*); Putnam Co. (Grimes *673;*



Figs. 1-8. Leaves of Convolvulaceae. 1 and 2, *Quamoclit coccinea;* 3 and 4, *Ipomoea hederacea;* 5 and 6, *I. purpurea;* 7 and 8, *I. pandurata.*

Yuncker in 1920); Shelby Co. (Mrs. Deam *11,580*); Spencer Co. (Deam *37,487*); Tippecanoe Co. (Dorner in 1900); Warrick Co. (Deam *37,661*); Wells Co. (Deam in 1897 and in 1903).

5. Ipomoea lacunosa.

Figs. 9-12.

Ipomoea lacunosa L., Sp. Pl. 161. 1753.

Plants smooth or hairy; leaves entire, or, more commonly, lobed or angled; flowers white or sometimes pink, red or purplish; sepals pointed and bristly hairy, chiefly along the margin; peduncles mostly shorter than the petioles, one to several flowered.

Common in cultivated fields, along river banks and low ground.

Specimens examined:—Clark Co. (Deam *5,432; 7,157; 12,095*); Clay Co. (Deam *37,781*); Floyd Co. (Deam *14,009*); Gibson Co. (Deam *9,934*); Greene Co. (Deam *37,751; 37,947*); Jackson Co. (Deam *38,063*); Jefferson Co. (Coulter in 1876; Deam *18,849*); Knox Co. (Deam *32,934*); Owen Co. (Mrs. Deam *10,204* in part with *Convolvulus sepium*); Perry Co. (Deam *33,223; 33,224; 37,344*); Posey Co. (Deam *22,337*); Putnam Co. (Grimes *251;* Yuncker in 1920); Spencer Co. (Deam *37,491*); Sullivan Co. (Deam *18,263*); Warrick Co. (Deam *37,660*); Washington Co. (Deam *18,978*).

6. Convolvulus spithamaeus.

Figs. 31-16.

Convolvulus spithamaeus L., Sp. Pl. 158. 1753.

Plants pubescent, usually not more than one foot high, erect, infrequently showing a tendency to twine; petioles mostly not more than one-fourth the length of the blade, in rare specimens slightly longer; peduncles exceeding the petioles; bracts mostly oval or, rarely cordate.

In dry soil on hillsides, river banks, etc.

Specimens examined:—Clarke Co. (Deam *6,481; 6,581*); Harrison Co. (Deam *23,399*); Noble Co. (Deam *6,776*); Porter Co. (Deam *20,060*); Steuben Co. (Deam in 1904); Tippecanoe Co. (Deam in 1901); Wells Co. (Deam in 1899); Whitley Co. (Deam *23,707*).

7. Convolvulus japonicus.

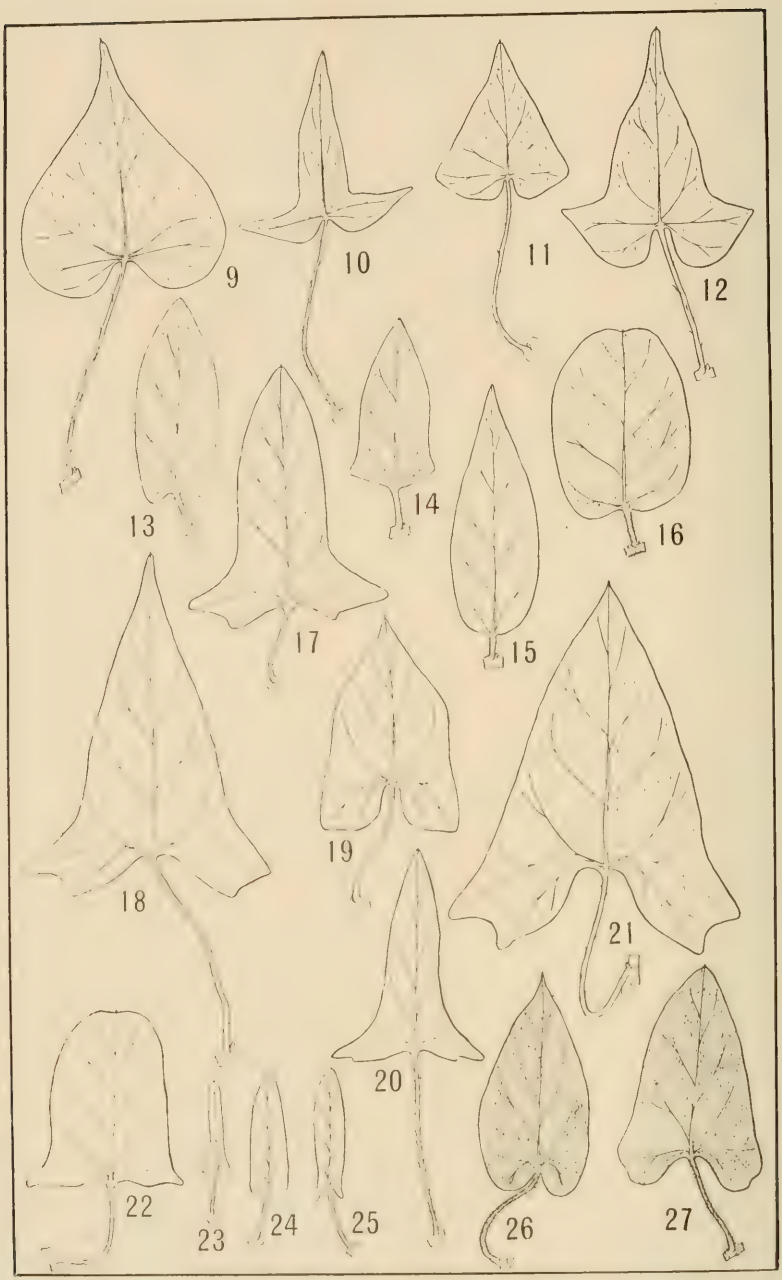
Fig. 17.

Convolvulus japonicus Thunb., Fl. Jap. 85. 1784.

Plants hairy; petioles much shorter than the blade; peduncles longer than the petioles; flowers double.

In moist, waste places. Rare.

Specimens examined:—Putnam Co. (Yuncker *1,352*); Tipton Co. (Grimes *942*).



Figs. 9-27. Leaves of Convolvulaceae. 9-12, *Ipomoea lacunosa;* 13-16, *Convolvulus spithamaeus;* 17, *C. japonicus;* 18 and 19, *C. sepium;* 20 and 21, *C. fraterniflorus;* 22-25, *C. arvensis;* 26 and 27, *C. repens.*

8. Convolvulus sepium.

Figs. 18 & 19.

Convolvulus sepium L., Sp. 153. 1753.

Plant smooth or slightly hairy; peduncles equal to or longer than the petioles and only one in each axil.

Common throughout the State in moist situations.

Specimens examined:—Allen Co. (Deam *1,359*); Brown Co. (Deam *11,200*); Floyd Co. (Deam *37,203*); Hamilton Co. (Mrs. Deam *8,711*); Hendricks Co. (Mrs. Deam *11,230*); LaPorte Co. (Deam *36,706*); Noble Co. (Deam *14,323*); Owen Co. (Mrs. Deam *8,966;* Mrs. Deam *10,204* in part with *Ipomoea lacunosa*); Perry Co. (Deam *37,388A*); Putnam Co. (Grimes *646;* McDougall in 1888; Yuncker *1,294*); Ripley Co. (Deam *13,801*); Shelby Co. (Mrs. Deam *11,365*); Steuben Co. (Deam *1,255*); Tipton Co. (Mrs. Deam *14,105*); Vermillion Co. (Deam *37,926*); Warrick Co. (Deam *37,593*); Wells Co. (Deam in 1901 and in 1903).

9. Convolvulus fraterniflorus.

Figs. 20 & 21.

Convolvulus fraterniflorus Mackenzie & Bush, Rept. Mo. Bot. Garden 16:104. 1905.

Plants commonly hairy; peduncles ordinarily two or more in each axil, mostly shorter than the petioles; bracts sparingly hairy.

Mackenzie and Bush differentiated this species from *Convolvulus sepium* chiefly on the following characters: *Plant pubescent; peduncles angled and winged, ordinarily more than one in each axil and commonly shorter than the petioles; floral bracts cordate.* This combination of characters is not at all constant in our Indiana specimens. The specimens here considered as being this species were chosen mainly on the number and length of the peduncles. It is believed that a study of a larger number of specimens collected from a more extended range would show that this species is at the most worthy of but varietal distinction.

In moist situations.

Specimens examined: Clay Co. (Deam *37,782*); Greene Co. (Deam *37,773*); Hancock Co. (Mrs. Deam *9,073*; Deam *37,840*); Knox Co. (Deam *17,059A*).

10. Convolvulus repens.

Figs. 26 & 27.

Convolvulus repens L., Sp. Pl. 153. 1753.

Plants trailing, densely hairy; petioles mostly more than one-fourth as long as the blade; basal lobes of the leaves rounded; peduncles exceeding the petioles; bracts mostly cordate.

This species may be confused with some specimens of *Convolvulus spithamaeus* showing a tendency to twine, but it differs mainly in the degree of pubescence, length of plant and of petioles and in the shape of the leaves and bracts.

Along roadsides and in fields.

Specimens examined: Crawford Co. (Deam *8,434; 20,443;* Schneck in 1893); Harrison Co. (Deam *23,318*).

11. Convolvulus arvensis.

Figs. 22-25.

Convolvulus arvensis L., Sp. Pl. 153. 1753.

Plants smooth; leaves and flowers mostly smaller than in the other Indiana species; the bracts small and at some distance from the flower; peduncles much exceeding the petioles.

Along roadsides and in waste places generally.

Specimens examined: Dearborn Co. (Deam *12,444*); Jefferson Co. (Deam *13,408*); Lake Co. (Deam *2,439*); Marion Co. (Deam *6,956*); Putnam Co. (Grimes *2,142;* Wilson in 1893; Yuncker *1,356*); Tipton Co. (Grimes *945*); Wells Co. (Deam in 1897).

Explanation of Plates.

The sketches were made by laying the leaves on paper and drawing their outline. The drawings have been reduced so that they are now about one-half the natural size of the leaves.

PLANTS OF WHITE COUNTY—V.

Louis F. Heimlich, Purdue University.

In this paper 117 additional species and varieties of the White County, Indiana, flora are reported. This makes the total number of wild plants of the county reported by the author 387.

The author has spared no pains to make the following list as correct as possible. Practically all specimens were checked by C. C. Deam, Bluffton, Indiana. The Rosa species were identified by P. A. Rydberg, New York Botanical Garden. The Salix species were identified by C. R. Ball; the Malus and Crataegus species by W. W. Eggleston, both of the U. S. Department of Agriculture. The determination of numbers 661, 673, 677, 681, 682, 685, 686, 699, 700, 701, 703, 707, 710, 712, 739, 742, 745, 746, 747, 748, 753, 755, 763, 775, 776, 777, 780, 781, 782, 783, and 788 is authorized by the Gray Herbarium, Harvard University.

All species reported in this paper were collected in the central and northeastern part of the county. Species numbers 649 to 688 and numbers 827 and 828 were collected on April 21 and 23, 1922; numbers 690 to 735 were collected on May 27 and 28, 1922; numbers 739 to 825 were collected on August 30 and 31, and September 2 and 3, 1922. These numbers follow the species names and indicate the specimen numbers in the author's collection.

It is believed that the following species and varieties included in the list are new to the state or merit special reference.

Ranunculus hispidus Michx. var. *falsus* Fernald.
Rubus pergratus Blanchard.
Lespedeza capitata Michx. var. *stenophylla* Fernald & Bissell.
Solidago caesia L. var. *axillaris* (Pursh) Gray.
Xanthium pennsylvanicum Wallr.

Brief notes are attached to these and certain other interesting species in the general list below.

Equisetaceae.

Equisetum arvense L. Field horsetail. Nos. 651, 688. See fig. 1.
Equisetum kansanum Schaffn. (*E. laevigatum* A. Br.) No. 703. Smooth scouring rush.

Typhaceae.

Typha latifolia L. Broad-leaved cat-tail. No. 754

Gramineae.

Digitaria sanguinalis (L.) Scop. (*Syntherisma sanguinale* (L) Dulac) No. 777. Large crab grass.
Panicum scribnerianum Nash. Scribner's panic grass. No. 699.
Setaria lutescens (Weigel) Hubbard. (*S. glauca* (L.) Beauv. of Gray's Manual, or the *Chaetochloa glauca* (L.) Scribn. of Britton and Brown). Common or yellow foxtail. No. 781. For revised nomenclature see Rhodora Vol. 18:232:1916.
Cenchrus tribuloides L. Sand-bur or bur-grass. No. 768.

"Proc. 38th Meeting, 1922 (1923)."

Stipa spartea Trin. Porcupine-grass. No. 708. Grows on dry, sandy hill-sides.

Muhlenbergia sylvatica Torr. (*M.-M. umbrosa* Scribn. of B. & B.) Woodland dropseed. No. 780.

Phleum pratense L. Timothy. No. 784. Escaped and established plant of waste places and roadsides.

Eleusine indica Gaertn. Wire-grass or crab-grass. No. 783.

Eragrostis purshii Schrad. Pursh's love-grass. No. 775.

Eragrostis cilianensis (All.) Link. This is *E. megastachya* (Koeler) Link. Syn. *E. Major* Host. of Gray's Manual. Strong-scented love-grass. No. 776.

Fig. 1. Field Horsetail *Equisetum arvense L.* A group of fertile stems growing in a moist sandy soil in south part of Reynolds, April 23, 1922.

Poa annua L. Annual or dwarf meadow-grass, or low spear-grass. No. 788.

Festuca octoflora Walt. Slender fescue-grass. No. 701.

Hordeum jubatum L. Squirrel-tail grass. No. 786.

CYPERACEAE.

Cyperus aristatus Rottb. (*C. inflexus* Muhl. of B. & B. ?) Awned cyperus. No. 746.

Eleocharis obtusa (Willd.) Schultes. Blunt spike-rush. No. 742.

Eleocharis capitata (L.) R. Br. Capitata spike-rush. No. 710. According to the Gray Herbarium this is the *E. tenius* (Wild) Schultes of the present manual.

Fimbristylis autumnalis (L.) R. & S. Slender fimbristylis. No. 745.

Scirpus validus Vahl. American great bulrush. No. 749.

Hemicarpha micrantha (Vahl.) Pax. Common hemicarpha. No. 747.

ARACEAE.

Symplocarpus foetidus Nutt. Skunk cabbage. No. 669.

JUNCACEAE.

Juncus tenuis Willd. Slender or yard rush. No. 782.

Juncus acuminatus Michx. Sharp-fruited rush. No. 748.

Luzula campestris (L.) D.C. var. *bulbosa* Wood. Bulbous common wood-rush. (*Juncoides bulbosum* (Wood) Small of B. & B.) According to Deam this is the common form of Luzula in Indiana. He says it probably occurs in every county.

Fig. 2. White adder's tongue or white dog's-tooth violet. *Erythronium albidum* Nutt. Very plentiful in thickets and wooded areas on the western protected bluff near the mouth of Pike creek. April 21, 1922.

LILIACEAE.

Allium canadense L. Meadow garlic. No. 720.

Erythronium albidum Nutt. White adder's-tongue. No. 657. See figure 2.

Trillium sessile L. Sessile-flowered wake-robin. No. 656.

Smilax lasioneuron Hook. Carrion-flower. This species has usually been reported under the name *S. herbacea* L. var. *pulverulenta* Michx. See Bull. Torrey Club Vol. 43:417:1916. No. 732.

DIOSCOREACEAE.

Dioscorea villosa L. Wild yam-root or colic-root. No. 803.

IRIDACEAE.

Iris versicolor L. Larger blue flag. No. 702.

Sisyrinchium atlanticum Bicknell. Eastern blue-eyed grass. Reported last year by Deam as new to Indiana. Proc. Ind. Acad. Sci. 1921:102. Seems to be the common species near Reynolds. Nos. 690, 709.

ORCHIDACEAE.

Habenaria bracteata (Willd.) R. Br. Long-bracted orchid. Collected in low flat woods near mouth of Big Monon Creek. Rare. No. 717.

SALICACEAE.

Salix alba L. White or common or European willow. No. 828.

Salix cordata Muhl. Heart-leaved willow. Nos. 653♂, 827♀. In the Proc. Ind. Acad. Sci. 1918:447-450 I reported *S. missouriensis* Bebb. as occuring in Indiana—a new record, basing my report on the identification of a specimen by an authority. *S. cordata* Muhl., here reported is based on determinations by Mr. C. R. Ball. Considering *S. missouriensis* Bebb. as a distinct species, the author plans further investigations seeking to verify or disqualify its presence in White County.

Salix tristis Ait. Dwarf gray willow. No. 679♀.

URTICACEAE.

Urticastrum divaricatum (L.) Kuntze. (*Laportea canadensis* Gaud.) Canada nettle. No. 799.

SANTALACEAE.

Comandra umbellata (L.) Nutt. Bastard toad flax. Nos. 693, 195.

POLYGONACEAE.

Rumex obtusifolius L. Broad-leaved or bitter dock. No. 785.

AMARANTHACEAE.

Amaranthus blitoides S. Wats. Prostrate amaranth. No. 773.

CARYOPHYLLACEAE.

Arenaria lateriflora L. Blunt-leaved sandwort. No. 735.

Agrostemma githago L. Corn cockle or corn campion. No. 728.

PORTULACACEAE.

Portulaca oleracea L. Purslane. No. 774.

RANUNCULACEAE.

Ranunculus hispidus Michx. var. *falsus* Fernald. No. 661. This variety of the hispid buttercup is new to the state. The specimen was checked at the Gray Herbarium. Literature covering this group in Rhodora Vol. 22:30-31:1920 was not available. Specimen from near mouth of Pike creek.

Anemonella thalictroides (L.) Spach. Rue anemone or wind-flower. No. 655.

Anemone canadensis L. Canada anemone. No. 727.

Isopyrum biternatum (Raf.) T. & G. False rue anemone. No. 658.

MENISPERMACEAE.

Menispermum canadense L. Canada moonseed. No. 733.

BERBERIDACEAE.

Caulophyllum thalictroides (L.) Michx. Blue cohosh. No. 663.

LAURACEAE.

Benzoin aestivale (L.) Nees. Spicebush. Nos. 671, 824.

FUMARIACEAE.

Dicentra cucullaria (L.) Torr. Dutchman's breeches. No. 654. See figure 3. Minor Farm, near mouth of Pike creek, in a thicket at the edge of a pool.

CRUCIFERAE.

Cardamine douglassii (Torr.) Britton. Purple cress. No. 665.

Cardamine parviflora L. Small-flowered bitter-cress. No. 677.

Fig. 3. Dutchman's breeches. *Dicentra cucullaria* (L.) Torr. Common over bluffs north of mouth of Pike creek. Photograph shows a plant growing in sandy soil on the steep border of pool surrounded by a thicket. April 21, 1922.

CRASSULACEAE.

Penthorum sedoides L. Ditch or virginia stonecrop. No. 750.

SAXIFRAGACEAE.

Mitella diphylla L. Bishop's cap. No. 672.

Ribes cynosbati L. Prickly wild gooseberry. No. 670.

ROSACEAE.

Malus lancifolia Rehder. (*M. coronaria*, of manuals, in part.) Narrow-leaved crab apple. No. 815. Near mouth of Pike creek, a tree about 8½ inches in diameter, b.h., and from 25-30 feet high. Specimen collected Sept. 3, 1922. Tree at this time bearing an abundant crop of apples, 1¼ inches in diameter and ⅞ inch high, long peduncled.

Associated with *Malus ioensis* (Wood) Britton, No. 814, tree 2½ inches in diameter, 12 feet high, apples 1⅝ inches in diameter, 1⅜ inches high, short peduncled. Also associated with the next.

Crataegus mollis (T. & G.) Scheele. Red-fruited or downy thorn. No. 813. Fruit abundant, ⅞ inch in diameter.

Rubus pergratus Blanchard. Square blackberry. No. 712. This species has not been reported for Indiana. Rydberg in Flora of North America gives its distribution as Maine to Ontario to Iowa. Specimen taken from a sandy ridge at edge of a woods about one mile northeast of Reynolds. In flower May 27.

Rosa blanda Ait. Smooth or meadow rose. No. 730. This rose forms several hybrids. My No. 722, according to Rydberg, seems to be *R. blanda* Ait. X *R. carolina* L. *R. carolina* L. is the *R. humilis*, Marsh. of Gray's Manual. It is also the same as *R. perriflora* Ehrh., *R. pennsylvanica* Wang., *R. caroliniana* Michx., *R. pratensis* Raf.? It is *not* the *R. carolina* L. as described in either Gray's Manual or Britton and Brown's Illustrated Flora. These should both be *R. palustris* Marsh. For explanation see Rydberg: Contributions from the New York Botanical Garden, No. 220, Notes on Rosaceae, 1920, or the same in Bulletin of the Torrey Botanical Club 47:45-66, Mar. 10, 1920. My report of *R. humilis* Marsh. (Proc. Ind. Acad. Sci. 1920:224) in accordance with the above should in name be changed to *Rosa carolina* L.

Rosa rubiginosa L. Sweetbrier or eglantine. No. 731.

Prunus virginiana L. Choke cherry. No. 724. This is the species described in Gray's Manual. This species and *P. serotina* Ehrh., which are merged in Britton and Brown's Illustrated Flora, are considered distinct species by the writer.

LEGUMINOSAE.

Cassia marilandica L. Wild or american senna. No. 806. This species was reported for Indiana long ago (Coulter's Catalog, 1899, with references from many counties). Neither Britton and Brown, 2nd edi. 1913, nor Gray 7th edi. 1908, credit it to Indiana.

Baptisia leucantha T. & G. Large white wild indigo. No. 825. In flower Sept. 3, 1922.

Trifolium arvense L. Rabbit-foot, old-field or stone clover. No. 816. On steep, hard, dry bluff of Tippecanoe river just below bridge at Norway. Associated with *Campanula rotundifolia* L.

Cracca virginiana L. (*Tephrosia virginiana* (L.) Pers.) Catgut, wild sweet-pea or goat's rue. No. 763.

Lespedeza hirta (L.) Hornem. Hairy bush-clover. No. 763.

Lespedeza capitata Michx. var. *stenophylla* Fern. & Biss. This variety is new to the state. The variety is described by Fernald and Bissell in Rhodora Vol. 14:92:1912. The specimen here reported was checked at the Gray Herbarium. Specimen taken from along the Pennsylvania railroad, east of Reynolds, growing in dry, sandy soil. No. 739.

Vicia americana Muhl. American or purple vetch. No. 721.

Strophostyles helvola (L.) Britton. Trailing wild bean. No. 789.
Falcata comosa (L.) Kuntze. (*Amphicarpa monoica* Ell.) Hog peanut. No. 798.

LINACEAE.

Linum virginianum L. Wild or slender yellow flax. No. 753.

POLYGALACEAE.

Polygala verticillata L. Whorled milkwort. No. 770.

BALSAMINACEAE.

Impatiens biflora Walt. Wild touch-me-not. No. 800.

VITACEAE.

Vitis aestivalis Michx. Summer or pigeon grape. No. 821. In a low, moist woods near mouth of Big Monon creek. The vines reached the high tree-tops. The main stem measured 19 inches in circumference.
Vitis vulpina L. Riverside or sweet-scented grape. No. 808.

CISTACEAE.

Helianthemum bicknellii Fernald. (*H. majus* B.S.P. of Gray's Man. *Crocanthemum majus* (L.) Brit. of B. & B.) Hoary frostweed. No. 707.

VIOLACEAE.

Viola sororia Willd. Wooly blue violet. Nos. 652, 660.
Viola scabriuscula Schwein. Smoothish yellow violet. No. 662.
Viola primulifolia L. var. *villosa* A. Eaton. No. 163. The following is an extract of a letter received from Ezra Brainard in answer to his receipt of my leaflet "The Primrose-leaved Violet in White County, Proc. Ind. Acad. Sci. 1914:213-217." "The drawing of your specimens seems to make them Eaton's var. *villosa*, a form commonly found in the South as far West as Calcasien County, La. (lat. 30½°). Its occurrence in Ind. Lat. 40° 35′, about 700 miles further north, is surprising. This pubescence in your plant may, however, be an instance of the general law that low temperature and high humidity, as in your small mucky bog, favor pubescence, while high temperature and low humidity tend to do the opposite." See Brainerd, Violets of North America, Vt. Agr. Exp., Sta. Bul. 224: Dec., 1921, p. 87, also pp. 64 and 65. Pitt. 3:315 May, 1898.

ONAGRACEAE.

Ludwigia palustris L. Marsh purslane or false loose strife. No. 741.

HALORAGIDACEAE.

Proserpinaca palustris L. Mermaid-weed. No. 678.

UMBELLIFERAE.

Zizia aurea (L.) Koch. Early or golden meadow parsnip. No. 696.
Daucus carota L. Wild carrot. No. 790.

ERICACEAE.

Vaccinium vacillans Kalm. Low blueberry. No. 685.

GENTIANACEAE.

Gentiana saponaria L. Soapwort gentian. No. 771.

CONVOLVULACEAE.

Cuscuta gronovii Willd. Gronovius' dodder. No. 755. On willows.

POLEMONIACEAE.

Phlox pilosa L. Downy or prairie phlox. No. 698.

Phlox bifida Beck. Cleft phlox. No. 684.

HYDROPHYLLACEAE.

Hydrophyllum virginianum L. Virginia waterleaf. No. 729.

BORAGINACEAE.

Lappula virginiana (L.) Greene. Virginia stickseed. No. 807.

Mertensia virginica (L.) DC. Virginia cowslip. No. 659.

Lithospermum arvense L. Corn gromwell. No. 681.

Lithospermum canescens (Michx.) Lehm. Hoary puccoon. No. 682.

LABIATAE.

Scutellaria lateriflora L. Mad-dog or blue skullcap. Nos. 751, 792, 801.

Nepeta hederacea (L.) Trevisan. Ground ivy. No. 650.

Mentha spicata L. Spearmint. Nos. 760, 796.

SCROPHULARIACEAE.

Mimulus ringens L. Square-stemmed monkey-flower. Nos. 743, 795.

Gratiola virginiana L. Clammy hedge-hyssop. No. 711.

Veronica scutellata L. Marsh or skullcap speedwell. No. 713.

Veronica peregrina L. Purslane speedwell. No. 705.

Afzelia macrophylla (Nutt.) Kuntze. Mullen foxglove. No. 812.

BIGNONIACEAE.

Bignonia radicans L. (Tecoma) Trumpet-vine. No. 819. Growing in low, moist ground near mouth of Big Monon creek.

CAPIFOLIACEAE.

Triosteum aurantiacum Bicknell. Scarlet-fruited horse-gentian. No. 726.

CAMPANULACEAE.

Campanula rotundifolia L. Harebell or blue bells of Scotland. No. 817. Many-flowered form. On steep, dry bluff of the Tippecanoe river just below the bridge at Norway. Associated with *Trifolium arvense* L.

COMPOSITAE.

Eupatorium purpureum L. Joe-pye or trumpet-weed, tall or purple boneset. See Rhodora Vol. 22:64.

Eupatorium urticaefolium Reichard. White snake-root. No. 791.

Solidago caesia L. Blue-stemmed or wreath golden-rod. No. 802.

Solidago caesia L. var. *axillaris* (Pursh) Gray. No. 822.

This variety has not been reported for Indiana. It seems to be an extremely doubtful variety, being perhaps only a simple stemmed form of the species. Britton and Brown do not recognize the variety, nor do they even make mention of the variety *paniculata* of Gray. According to Deam most of the Indiana specimens do not agree with the description of the species as given in Gray, but more nearly with the variety *paniculata*. The variety is here reported for the information of other collectors.

Solidago rigida L. Stiff or hard-leaved golden-rod. No. 740.

Antennaria fallax Greene. Nos. 673, 686. See figure 4. Reported by Deam for Indiana, Proc. Ind. Acad. Sci. 1914. Both of my specimens were checked by the Gray Herbarium. *S. ambigens* Fernald is a synonym. Neither name is listed in Britton and Brown, Illustrated Flora, 2nd. edi.

Fig. 4. Cat's-foot or everlasting. *Antennaria fallax* Greene. A part of a large colony of these plants growing on the southeastern edge of a sand hill about one-fourth mile east of Reynolds. April 23, 1922.

Xanthium pennsylvanicum Wallr. Pennsylvania clotbur. No. 793. This is a new name in the list of plants for Indiana. Perhaps most of the reports for *X. canadense* Mill. should be referred to this species. The genus has long been in an uncertain condition. For the new treatment of the genus see North American Flora Vol. 33:37-44: 1922.

Heliopsis helianthoides (L.) Sweet. Ox-eye or false sunflower. No. 810.

Rudbeckia laciniata L. Tall or green-headed cone-flower. No. 823.

Ridan alternifolius (L.) Britton. Wing-stem or yellow iron weed. No. 809.

Helenium autumnale L. False or swamp sunflower. No. 757.

Tanacetum vulgare L. Tansy. No. 761. This plant is growing wild in several places in the county according to recent observations. (See Proc. Ind. Acad. Sci. 1920:223.)

19--25870

THE USTILAGINALES OF INDIANA III.[1]

H. S. Jackson, Purdue University Agricultural Experiment Station.

The following notes on the smuts of Indiana are presented at this time as the second supplement to the paper bearing the same title which was published in the Proceedings of the Indiana Academy of Science for 1917, pp. 119-132. The first supplement was included in the Proceedings for 1920, pp. 157-164.

In the two previous papers a total of 57 species have been recorded for the state. The present paper includes records for seven additional species, bringing the total number found in Indiana to 64. Additional notes are included on some of the previously recorded species. As in the previous papers each species is given a number and these are consecutive for the three papers. Unless otherwise stated the collections were made by the writer.

NOTES ON SPECIES PREVIOUSLY RECORDED.

33. Entyloma compositarum Farl.

On Carduaceae:

Ratibida pinnata (Vent) Barnh. (*Lepachys pinnata* (Vent) Torr. & Gray.) Bayle's Mills, Tippecanoe Co., June 12, 1922, with H. H. Whetzel.

The collection reported in the 1917 list on *Ambrosia elatior* L. has been transferred to *Entyloma polysporum* cf. 37. No collections on Ambrosia referrible to *E. compositarum* have yet been made in Indiana.

37. Entyloma polysporum (Peck) Farl.

On Ambrosiaceae:

Ambrosia elatior L., LaFayette, July 2, 1889, J. C. Arthur; Ladoga, July 27, 1920, P. J. and H. W. Anderson.

Ambrosia trifida L., West Lafayette, August 21, 1916; Dayton, September 2, 1920.

In the 1917 report it was stated that, while this species was listed from Indiana by Clinton (N. Am. Flora 7:62. 1906), we had seen no specimens. The above collections have since been encountered. I am indebted to Dr. G. P. Clinton for the identifications. The collection first mentioned was previously recorded as *E. compositarum* but should be transferred to this species.

SPECIES NEW TO INDIANA.

Ustilaginaceae.

58. Sorosporium ellisii Wint. Hedwigia 22:2. Ja. 1883.—Bull. Torrey Club. **10**:7. Ja. 1883.

On Poaceae:

Andropogon virginicus L., One mile west of French Lick, October 5, 1921.

Schizachyrium scoparium (Michx.) Nash., Thayer, Newton Co., May 1921 and September 29, 1921.

[1] Contribution from the Botanical Department of the Purdue University Agricultural Experiment Station.

"Proc. 38th Meeting, 1922 (1923)."

In this species the entire inflorescence is reduced to a smutty mass of spores as distinguished from the next following species which attacks only the individual ovaries. In the original description, this species was confused with another on *Aristida dichotoma*.[2]

59. Sorosporium everhartii Ellis & Gall. Jour. Myc. 6:32. 1890.

On Poaceae:

Andropogon virginicus L. One mile west of French Lick, October 5, 1921.

60. Sphacelotheca occidentalis (Seym.) Clinton Jour. Myc. 8:141. 1902.

Soroporum Ellisii occidentalis Seym.; Ellis & Ev. N. Am. Fungi *2,265*. 1889.

On Poaceae:

Andropogon furcatus. Muhl. In flat sterile place in woods on south side of Lake Maxinkuckee, Marshall County, September 14, 1921. C. C. Deam, *14,722*.

This species occurs in the individual ovaries of the grass and is doubtless not uncommon, but has not before been recorded so far east.

61. Ustilago oxaldis Ellis & Tracy, Jour. Myc. 6:77. 1890.

On Oxalidaceae:

Oxalis stricta L. Near English, May 24, 1922; near Huntingburg, May 25, 1922.

This is a species of wide distribution in the eastern half of the United States. The sori occur in the seeds, the affected ovaries differing only slightly from the normal. Usually all the seed of diseased plants are affected.

TILLETIACEAE.

62. Doassansia martianoffiana (Thuem.) Schrot. Krypt. Fl. Sches. 3[1]:287. 1887.

Protomyces martianoffianus Thuem. Bull. Soc. Nat. Mosc. 53[1]:207. 1878.

On Zannichelliaceae:

Potamogeton sp. Edge of Bass Lake, Starke County, June 18, 1921.

An inconspicuous species forming yellowish white spots on the leaves which later become reddish brown.

63. Entyloma serotinum Schroet. Bietr. Biol. Pfl. 2:437. 1877.

On Boraginaceae:

Mertensia virginica (L.) DC. Near Harrodsburg, May 7, 1921. J. M. Van Hook *3,865*.

64. Tilletia corona Schrib. Tracy & Earle, Bull. Torrey Club. 23:210. 1896.

On Poaceae:

Hamalocenchrus virginicus (Willd.) Britt. Northeast of Fairmount, October 3, 1915. C. C. Deam *19,314;* One mile southwest of French Lick, October 5, 1921.

This species causes rather conspicuous enlarged and deformed ovaries, only occasional ones in the inflorescence being infected.

[2] Cf. Jackson, H. S. Sorosporium Ellisii Wint., a Composite species. Bull. Torrey Club. 35: 148. 1908.

RECENT INDIANA WEEDS.[1]

ALBERT A. HANSEN,

Purdue University Department of Agricultural Extension.

New weeds appear practically every year in Indiana, usually through the medium of impure seed. Occasionally the newcomers flourish for a while, then practically disappear. Some species, however, make themselves thoroughly at home and frequently become so aggressive that they are a source of considerable loss and annoyance to the farmer. The great majority of our troublesome weeds are introduced species; for instance, only two of the nineteen species designated as noxious in the Indiana seed law are native plants.

The species considered in this paper include, (1) plants that are known to be troublesome elsewhere but have not been previously recorded as occurring in Indiana by authorities on the distribution of plants, (2) plants that have not been previously reported as troublesome weeds. This report covers the period from October 1, 1921, to October 1, 1922.

For verifying identifications, acknowledgment and thanks are due F. V. Coville, A. S. Hitchcock, and S. F. Blake, all of the United States Department of Agriculture, J. N. Rose of the Smithonian Institution and B. L. Robinson of the Gray Herbarium.

Perennial sow thistle (*Sonchus arvensis* L.). Found growing luxuriantly on the farm of Harry Warr, Brook, Indiana. Mr. Warr considers it a "very bad weed with roots that go down three feet."

The discovery of perennial sow thistle in Indiana is of importance since this species is one of the most troublesome weeds in America, particularly in the Red River Valley of Minnesota and North Dakota and in adjacent Canada. The plant causes greatest damage where a one-crop system of grain farming is practiced, consequently it is not thought that the species can become as troublesome in Indiana on account of the diversified farming practices that prevail. Nevertheless it is a noxious weed that should be guarded against.

Spotted knapweed (*Centaurea maculosa* Lam.). A well-established patch of spotted knapweed was found on the Lofland farm near Romney, Tippecanoe County. The occurrence of this species in Indiana is noteworthy since it is a close relative of the black knapweed, *Centaurea nigra*, considered a serious grassland weed in Europe and recently troublesome in New York.

Perennial peppergrass or hoary cress. (*Lepidium draba* L.) Found in LaGrange County. During recent years this species has become extremely troublesome in Utah, California, Colorado and other western states. The following statement is quoted from Bulletin 264 of the Colorado Agricultural Experiment Station.

"Recently the perennial peppergrass has become of such frequent occurrence in Colorado that unless prompt action be taken for its

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

"Proc. 38th Meeting, 1922 (1923)."

control it is almost certain to spread itself over most of the cultivated areas of the state. During the past season this station has received numerous urgent appeals for some definite advice concerning methods for controlling this pest."

Mexican clover. (*Richardia scabra* L.) A new weed that is appearing in abundance in fields in the northeastern part of Henry County. It is a very common weed in the southern states, particularly in the gulf states, although it rarely becomes very troublesome. The common name is misleading since the plant is not a clover but is a member of the Rubiaceae.

Lawn pennywort. (*Hydrocotyle rotundifolia* Roxb.) Recently reported as a new lawn weed in America in Department of Agriculture, Circular 165. Its distribution was reported as the District of Columbia, locally in Pennsylvania, and near Louisville, Kentucky. The species was discovered as a serious lawn pest in Evansville, Indiana, where it presents a difficult lawn problem. It is a native of southern Asia.

Welted thistle. (*Carduus crispus* L.) Occurs locally in the eastern states. The species was found established in Union County, Indiana. It is a perennial and a native of Europe and Asia.

Western brome grass. (*Bromus carinatus* Hook and Arn.) A native western perennial that is common on the Pacific Coast, was found on the farm of Smith Brothers, Middlebury, Indiana. Since immediate measures were taken for the destruction of the several patches found it is not likely that the species will persist.

Phacelia. (*Phacelia purshii* Buckl.) A native annual that is causing much damage to oats, clover and wheat in Rush and Wayne Counties. In one part of Rush County about 500 acres of clover and wheat were seriously infested during the spring of 1922. The plant seems to choke out the crop, causing an uneven stand. No record can be found of this species causing damage as a field weed in other sections of the United States.

Bermuda grass. (*Capriola dactylon* (L.) Kuntze.) Bermuda grass, ordinarily considered to be a weed in the southern states only, is locally troublesome throughout Indiana, where it is frequently mistaken for quack grass. Although one of the worst weeds in the south, the species is at the same time a valuable lawn and pasture plant in the southeastern states. Shallow fall plowing followed by a good shade crop should kill Bermuda grass.

Johnson grass. (*Holcus halepensis* L.) The statement is frequently heard that Johnson grass cannot persist north of the Ohio River. The plant has been established in Indiana for a number of years and is known to be troublesome as far north as Vigo County, particularly in the vicinity of Terre Haute where it covers about five hundred acres of land. The farmers contend that it is one of the worst weeds in the county. It is said to have been introduced into Vigo County by means of western hay. Johnson grass is also troublesome in Scott County.

Gum Plant. (*Grindelia robusta* Nutt.) A native western species that occurs principally along the California coast, has been reported

as growing in sandy land near Ontario, LaGrange County. Specimens have been collected by C. C. Deam.

Wild Corn. (*Andropogon sorghum,* var. *drummondii* Hack.) A serious problem in corn fields on overflow land along the Ohio and Wabash Rivers in the southwestern part of the state, particularly in Vanderburg and Posey Counties.

CONCLUSION.

The Purdue Agricultural Experiment Station desires to keep in touch with new plants in Indiana that are apt to prove troublesome. Specimens of strange plants that exhibit weedy tendencies will be welcomed. It is thought that a great deal of trouble and expense can be saved to the farmers of the state if prompt action is taken as soon as new weeds are noted.

WILD CORN, A SERIOUS WEED IN INDIANA.[1]

ALBERT A. HANSEN, Purdue University Agricultural Experiment Station.

Wild corn is a member of the sorghum tribe that causes heavy losses on overflow land along the Ohio and Wabash Rivers in Posey and Vanderburgh counties, Indiana, and along the Ohio River in Henderson County, Kentucky.

The problem presented is very unusual. The seeds, which are produced in large numbers, are carried by the flood water. When the water subsides, the seeds are left on the soil, ready to germinate with the corn crop. The young wild corn plants resemble corn seedlings so closely that recognition is difficult and they become large plants before they can be identified. The damage done is so heavy that in some cases infested corn crops have been left unharvested. The seriousness of the situation is indicated by the fact that a request for assistance in controlling this weed was recently received from forty-six farmers residing in Kentucky and Indiana. They represented a total of 21,186 acres of corn land 25.9 per cent or 5,487 acres of which was damaged by wild corn during 1921. During a weed survey recently conducted by the Agricultural Extension Department of Purdue University, wild corn was reported as the second worst weed in Posey County by County Agent W. E. Shrode.

Wild corn has been identified as *Andropogon sorghum drummondii* Hack, a wild variety of common sorghum. The plant is said to have been introduced from Africa by the early slave traders. It spread in the southern coastal states, particularly in Louisiana and Mississippi, but it was rarely found further north. In its southern range the plant was commonly called chicken corn. Although classed as a weed, it was sometimes used as a source of wild hay and for fall pasture. The seeds were also gathered occasionally for chicken feed. With the introduction

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

of cultivated sorghum and the consequent spread of the sorghum midge, wild corn almost disappeared throughout its range, due to the ravages of the insect. The existence of the plant in large areas along the Ohio river in Kentucky was unsuspected until announced by the writer a year ago.[2] The occurrence of wild corn as a serious weed problem along the Ohio and Wabash rivers in Indiana is an important economic problem. That the species is persisting is probably explained by the fact that Indiana is so far north as to be out of the range of the sorghum midge. Although a native of a warmer climate, the plant seems to be thoroughly acclimated in its northern home.

Controlling wild corn is far from an easy job. In Posey County the only successful control method practiced is thorough cultivation, including regular hoeing as soon as the weed is large enough to be recognized. One difficulty is that chance seedlings spring up throughout the growing season in spite of the most diligent hoeing. Some farmers reduce the damage considerably by delaying planting in the spring until after most of the wild corn seeds have sprouted. The young plants are then destroyed by plowing and preparing the seed bed for corn. There seems little hope for controlling the weed by crop rotation since corn is practically the only crop the farmers will grow on the overflow land.

A solution that suggests itself is the introduction and acclimatization of the sorghum midge. If this could be done, the wild corn would probably soon disappear since the midge prevents the production of viable seeds and wild corn is an annual plant, depending entirely upon seeds to reproduce. The introduction and acclimatization of the sorghum midge is a dangerous experiment, however, since the insect might attack the sorghum crop, which is worth about $1,000,000 annually in Indiana.

Surface cultivation in the fall in order to induce the germination of the seeds of wild corn seems to offer little hope as a remedy since most of the infested land is subject to overflow during late spring and early fall, and seeds are scattered over the fields during each overflow.

Since wild corn is an annual, it is possible that if all the plants were kept from seeding throughout a single season, the pest would disappear, providing none of the seeds remained viable in the soil during the second winter. Large scale co-operation of this type among farmers is theoretically possible but practically almost impossible. Until further knowledge is secured, late planting and thorough cultivation will have to be depended on as the best control measures available.

In addition to the economic phase of the subject, wild corn presents a problem of considerable interest to the plant ecologist.

[2]Chicken Corn, an Unusual Weed, Found Growing in River Lowlands in Kentucky. Weekly News Letter, U.S.D.A. June 29, 1921.

POLYEMBRYONY IN CERTAIN NUT BEARING PINES.

D. M. Mottier, Indiana University.

In seeds of nut bearing pines, "pinyon nuts", used for class study, the presence of two embryos in individual seeds has been observed from time to time. During the autumn of 1922, a member of the class called my attention to two well developed embryos of nearly the same size in a seed, probably of *Pinus edulis* Englemann, given him for study. Closer examination revealed the fact that in this seed three other smaller embryos were also present, making five in all, as shown in figure 1. The three smaller embryos are large enough to be recognized by the unaided eye. The figure represents the five embryos in proper proportion. In the three smaller embryos no indication of cotyledons could be recognized with the hand lens. The two larger embryos seemed to be mature as regards the differentiation of parts. The one near the chalazal end is perceptibly larger. In cases in which only one embryo is present

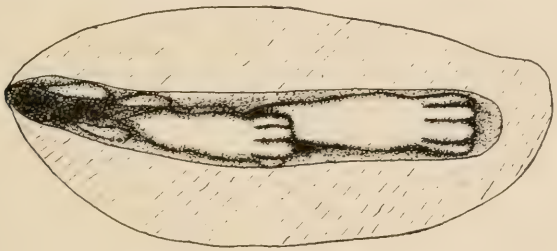


Fig. 1. One-half of endosperm of *Pinus edulus*, showing the five embryos in position. x 6.

in the mature seed, the length of the embryo is almost equal to the length of the endosperm.

As is well known, polyembryony in the genus Pinus results from the cleavage of the pro-embryo into four embryos, all of which tend to develop, but owing to competition, embryonal selection results, and only one embryo, as a rule, matures in the seed. If only one egg be fecundated, we have mono-zygotic cleavage polyembryony. But if two or more eggs are fecundated, as frequently happens in some species of pines (*P. laricio*), we have what may be termed poly-zygotic cleavage polyembryony. In Gymnosperms in which the embryonal cells do not separate, and one embryo develops from each fecundated egg, polyembryony can result only from two or more fecundated eggs. This is simple poly-zygotic polyembryony.

In cases of poly-zygotic cleavage polyembryony in Gymnosperms, it is very evident that among the numerous embryos that begin development, with apparently an equal start, the struggle for supremacy is very intense. The instance of figure 1 shows that the two larger were almost potentially equal, the one being unable to crowd out the other. Each, however, is about one-half the size of the single embryo normally

"Proc. 38th Meeting, 1922 (1923)."

surviving in the mature seed. Both were unable to obliterate completely the three smaller embryos by the time the seed matured.

What it is that enables the successful embryo or embryos to win out in the struggle, assuming that two or more have an equal start, can only be conjectured.

The writer has conducted a class in the embryology of Gymnosperms for many years, using chiefly *Pinus laricio*, and of the numerous pro-embryos in various stages of growth observed, the one which apparently had the upper hand seemed to be the one plunged more deeply chalazal-wards in the endosperm, but cases have been observed in which the deepest was not the largest.

Time and again it has been observed in microtome sections that embryos were entangled among the suspensors, some pointing directly towards the micropyle and growing in that direction. It would seem reasonable to assume that such embryos would be as well nourished as those growing downward into the endosperm.

For an admirable presentation of polyembryony in Gymnosperms the reader is referred to the following papers by John T. Buchholz: Suspensor and early embryo of Pinus. Bot. Gaz. 66: 185-228, 1918; Polyembryony among Abietineae. Bot. Gaz. 69: 153-167, 1920; Embryo development and polyembryony in relation to the phylogeny of conifers. Amer. Jour. Bot. 7: 125-145, 1920.

PHYTOPHTHORA ROT OF TOMATO, EGGPLANT, AND PEPPER.[1]

JAMES B. KENDRICK, Purdue University Agricultural Experiment Station.

A Phytophthora rot, apparently identical with buckeye rot of tomato appeared in epidemic form in an experimental plot of tomatoes at Lafayette, Indiana, August 1-3, 1921. The disease continued throughout the summer and destroyed about 40 per cent of the tomato fruits. A few weeks later, a very similar disease developed on eggplant and sweet pepper fruits growing adjacent to the tomatoes, and from all of these, the same Phytophthora was repeatedly isolated. With the Phytophthora isolated from tomato, successful inoculations were secured on eggplant and pepper fruits. The organism was repeatedly isolated from inoculated eggplant and pepper fruits. So far as has been determined, this disease has not been previously reported in Indiana under field conditions.

History.—The genus Phytophthora contains a number of species which are separated by apparently minor and none too stable differences. Rosenbaum[2] made an extensive comparative study of nine described species of Phytophthora and presented a tentative table for the separation of species based on his studies.

Sherbakoff[3] working in Florida, described a buckeye rot of tomatoes in 1917 which he attributed to an undescribed species of Phytophthora to which he gave the name, *P. terrestris.* Using the fungus isolated from tomato, he inoculated tomatoes, sweet peppers, watermelon fruit, lemons, and tubers of Irish potatoes and secured infection in every case.

Late blight of potatoes, caused by *Phytophthora infestans*, has been reported on tomatoes in West Virginia by Giddings.[4] It occurred on leaf, stem and fruit, causing a rot of the fruit. He reports serious losses due to blighting of the plants before many fruits were set. The organism, according to Giddings, is morphologically identical to *P. infestans* which causes a serious blighting of potatoes.

In 1915, Haskell[5] while stationed in Dutchess county, New York, observed a disease on eggplant fruit pedicles and calyces and a decay of a few of the younger fruits. The eggplants were growing adjacent to a field of potatoes which were badly infected with *P. infestans.* A comparison of the organism causing the disease on the eggplants with *P. infestans* from the potatoes showed that the two were identical.

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[1] Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, Lafayette, Indiana.

The writer wishes to express his appreciation to Dr. Max W. Gardner for helpful suggestions and criticisms.

[2] Rosenbaum, J. Studies of the Genus Phytophthora. Jour. Agr. Res. 8:233-276, 13 fig., 7 pl., 1917.

[3] Sherbakoff, C. D. Buckeye rot of tomato fruit. Phytopath. 7:119-129. 5 fig., 1917.

[4] Giddings, N. J. Potato and tomato diseases. West Virginia Agr. Exp. Sta. Bul. 165, 18-19. 1917.

[5] Haskell, R. J. Phytophthora infestans on eggplant in the United States. Phytopath. 11:504-505. 1917.

"Proc. 38th Meeting, 1922 (1923)."

Leonian[6] recently described a stem and fruit blight of peppers caused by a species of Phytophthora which he named *P. capsici*. Peculiar tuberous growths on the mycelium resembling sporangia were considered a distinctive morphological character of this species. No reference is made to Sherbakoff's work[7] on *P. terrestris*.

The morphological characters of the fungus causing the disease in Indiana do not agree with either *P. infestans* (Mont.) DeBary, or *P. capsici* Leonian, but do agree very closely with *P. terrestris* Sherb. The symptoms of the disease on tomato are very similar to the symptoms of buckeye rot of tomato as described by Sherbakoff[7], and therefore it seems likely that the causal organism of the disease of tomatoes, eggplants and peppers in Indiana is *P. terrestris*.

Distribution and Economic Importance.—Buckeye rot of tomatoes, caused by *P. terrestris* has been reported from Florida[7] where it has caused serious losses due to the rotting of the fruits, especially those touching or very near the ground. In 1919, Weimer observed buckeye rot on tomatoes in the U. S. Department of Agriculture experimental field plots at Arlington Farms, Virginia. In 1920, Jehle[8] reported the loss from buckeye rot of tomatoes to be one to two per cent in the coastal plain counties of North Carolina. Pritchard[9] the same year reported a 0.5 per cent loss on the experimental farms at Arlington, Va. It was also reported as causing loss of lower fruits in greenhouses in Indiana[9].

In 1921, Sherbakoff[11] reported the loss in Tennessee from buckeye rot to be approximately ten per cent, and Pritchard[10] again reported the disease prevalent on the experimental farm at Arlington, Va. The rot was reported on tomatoes shipped from Texas and Mexico in 1919 in the plant disease survey bulletin.

Buckeye rot is primarily a tropical or subtropical disease. It often causes serious losses in greenhouses in the north where tomatoes are grown under warm humid conditions.

It is possible that the organism causing buckeye rot may be carried from one locality to another in the soil on the roots of young plants. In 1920, about a hundred tomato plants grown in Georgia were put out in the experimental field at Lafayette, Ind. In 1921, tomatoes were grown on this same soil and it was in these tomatoes that the epidemic of buckeye rot occurred. Tomatoes were again grown there in 1922, but no buckeye rot developed, possibly due to drier weather conditions.

Symptoms.—The disease as observed in Indiana affects only the fruits of the host plants. The lesion first appears on the green tomato fruits as a very small web or lace-like blotch five to ten mm. in diameter. (Fig. 1, A). These spots look like a few dark-brown tan-

[6] Leonian, Leon H. Stem and fruit blight of peppers caused by Phytophthora capsici sp. nov. Phytopath. 12:401-408, 2 fig., 1922.

[7] Sherbakoff, *loc. cit.*

[8] Haskell, R. J. and Wood, Jessie. Diseases of field and vegetable crops in the United States in 1919. U.S.D.A. Plant Disease Bul., Supplement 10, p. 217, June 1, 1920.

[9] Haskell, R. J. and Wood, J. I. Diseases of field and vegetable crops in the United States in 1920. U.S.D.A. Plant Disease Bul., Supplement 16, page 224, June 1, 1921.

[10] Coons, G. H. Diseases of field and vegetable crops in the United States in 1921. U.S.D.A. Plant Disease Bul., Supplement 22, p. 328-329, July 20, 1922.

gled-threads embedded in the epidermis of the fruit. This develops rapidly into a dark water-soaked spot, and in a few days may increase to 20 to 30 mm. in diameter. Several spots often occur on the same fruit and later coalesce into one large spot. (Fig. 1, B). As the rot progresses dark-brown concentric rings or zones are formed in the diseased area, giving it the buckeye appearance. (Fig. 1, C). The fungus

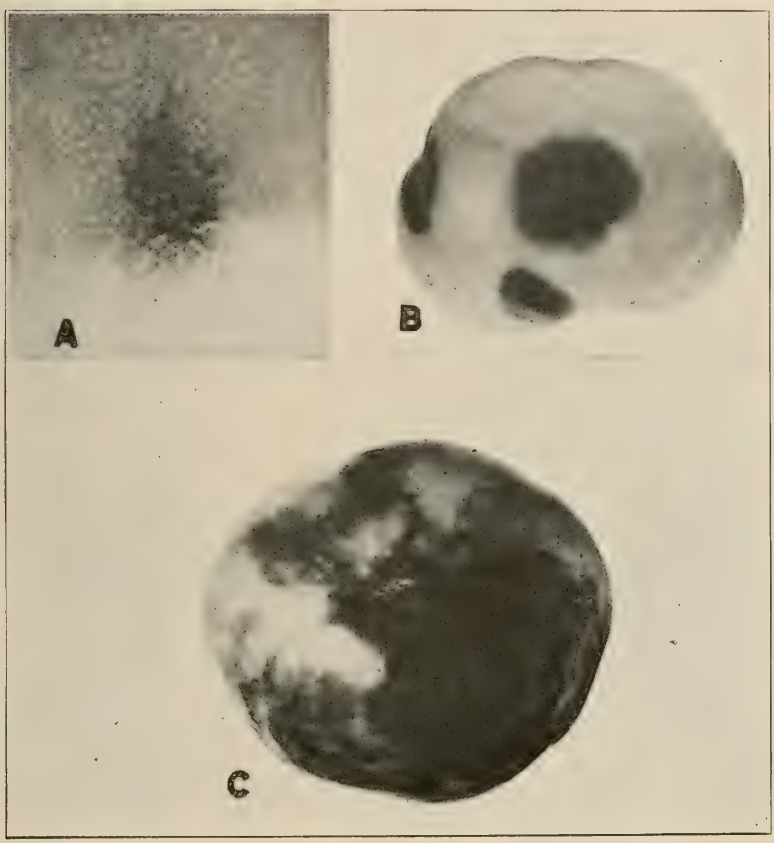

Fig. 1. *Phytophthora terrestris* on tomato fruit. *A*. Incipient infection showing the dark brown web- or lace-like early stage of the lesion (X3). *B*. Lesions three to four days older than the lesion in *A*. *C*. A later stage showing the concentric brown markings in the diseased area.

does not cause a marked disintegration of the tissues. The host cells are killed, but the tissue involved is firm until a later stage of the disease, by which time saphrophytic bacterial invaders have entered and caused a soft rot of the fruit.

On mature tomato fruits, the disease causes a premature ripening and decay. No young lesions were observed on ripe fruits, but young lesions were observed on green fruits of all sizes. From these observa-

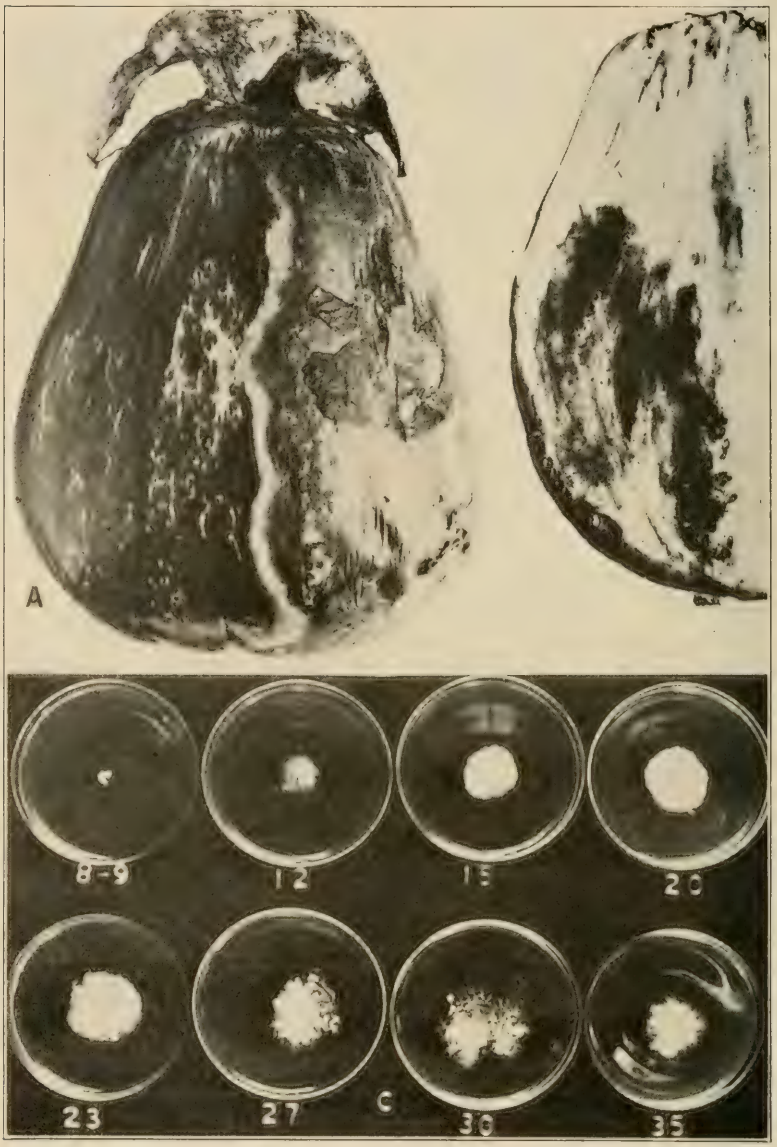

Fig. 2. *A*. Rot on eggplant fruit induced by inoculation with the Phytophthora isolated from tomato. The diseased fruit has separated from the stem, a condition which is characteristic of the disease on eggplant. *B*. Longitudinal section of an infected eggplant showing the darker infected tissue and discoloration of the vascular bundles over the entire surface, especially at the stem-end. *C*. Growth of the fungus after nine days incubation at different temperatures. The numbers denote the temperature on the centigrade scale.

tions, it seemed likely that the bulk of the infection took place when the fruits were green.

On the eggplant, the fungus produces a dark-brown spot on the fruit with a conspicuous light-colored border. (Fig. 2, A). When the fruit is cut open, the fungus is found to extend well into the flesh as evidenced by the dark-brown discoloration of the tissues. (Fig. 2, B). The fungus appears to advance most rapidly in the vascular bundles since these show as dark strands running out from the badly discolored area. (Fig. 2, B). Affected fruits drop from the stem prematurely and in no case was a fruit observed to remain on the stem after more than one-half the fruit had become involved. This premature dropping of the fruit from the stems is attributed to the invasion of the fibro-vascular tissues at the stem-end and a stimulation of the abscission process.

The symptoms on pepper are not as pronounced as on either tomato or eggplant. The first symptom is a small dark-green water-soaked spot. The lesion enlarges rapidly and before the rot involves one-half of the fruit, it drops from the plant. The somewhat wilted pedicels remain attached to the fruits and when cut longitudinally, show discolored vascular bundles. When these pedicels were incubated in a damp chamber, a fungus similar to the one isolated from the fruits grew out of them. The fungus penetrates the pedicels of the pepper fruits but apparently not the branches of the plant. In the eggplant, the fungus apparently does not invade the pedicel at all. In the case of peppers only the green fruits are susceptible.

The Fungus.—The fungus was readily isolated from infected tomato, eggplant and pepper fruits by planting small blocks of infected tissue, cut out aseptically, in poured plates of potato agar. In practically every case, a white, rather dense, spreading and somewhat tufted fungus developed from the tissue plantings. The organism grows well on potato agar, which has been used almost entirely in the laboratory cultural work.

The mycelium is at first continuous, but later becomes sparingly septate and branched. Peculiar distortions or tuberous outgrowths are very common on the mycelium in old cultures. Conidia are produced in cultures on potato agar in four to six days, but not abundantly. In Petri dish cultures on sterilized sugar beet and radish leaves in water, an abundance of conidia are produced in three days. Conidia are usually borne terminally, but often are intercalary, and are oval to oblong and papillate at the apex. The great majority of the conidia are uniformly oval in shape, especially in liquid cultures. The measurements of the conidia from the liquid cultures were 47.6x54.9 (45.9-50x53.2-55.8)μ, while from agar cultures they were 31x41 (29.5-33.5x33-92.5)μ. The conidia germinate either by swarm-spores or by one to three or more germ tubes.

Chlamydospores were produced rather abundantly, especially in old cultures. They were globose and measured 24.7 (27.5-27.9)μ. Oospores were found in old cultures. These were thick-walled and globose and measured 21 (17.5-26)μ.

The above description agrees closely with that given by Sherbakoff for *P. terrestris*, and since the symptoms on the tomato were identical with those described by the same author for buckeye rot of tomato, the organism causing the disease in Indiana is in all probability that species.

Inoculations.—Inoculation work was done in the field late in the summer of 1921 with cultures of the Phytophthora isolated from tomatoes. Eighteen eggplant fruits were inoculated by making a very slight wound on the surface of the fruit with a flamed scalpel and placing very small pieces of mycelial growth from agar cultures on the wounds. Nine of the 18 inoculated fruits developed the rot, from which the same Phytophthora was later reisolated.

Thirteen pepper fruits were similarly inoculated and ten of the 13 inoculated fruits developed the rot. Six pepper fruits were inoculated by placing fragments of an agar culture on the unwounded surface and four of the six developed the disease. The fungus was reisolated from these infected fruits.

Inoculation of green tomato fruits in moist chambers in the laboratory, both with and without wounding the surface, by placing fragments of agar cultures on the surface of the fruits and over the wounds, produced a typical Phytophthora rot.

The inoculation of six small watermelon fruits by making a slight wound near the blossom-end and placing small blocks of agar cultures over the wounds gave negative results.

On Nov. 30, 1921, potatoes were surface sterilized, sliced with a flamed scalpel and placed in sterile moist chambers and inoculated by placing mycelium from an agar culture on the cut surface and incubated at 23°C. and 27°C. No infection occurred.

Temperature Relations.—A series of cultures was grown at different temperatures to determine the optimum temperature for the mycelial development of the organism. A very small block of an agar culture was planted in the center of each of a number of poured plates of potato agar. These plates were then placed in moist chambers and incubated at the following temperatures: 8°-9°, 12°, 15°, 20°, 23°, 27°, 30°, and 35°C. Measurements of the diameter of the colonies were made at different intervals. The measurements made at the end of nine days are given in table 1.

TABLE 1. Growth of *P. terrestris* at Different Temperatures.

8-9°C.	12°C.	15°C.	20°C.	23°C.	27°C.	30°C.	35°C.
No growth.	20 mm.	30 mm.	32 mm.	35 mm.	35 mm.	50 mm.	32 mm.

From the above table it is evident that the optimum temperature for mycelial development is about 30° C. and that low temperatures are not favorable to its development. (These temperature relations are illustrated in figure 2, C.)

The fact that the organism attains its maximum development at a relatively high temperature in a humid atmosphere might explain the outbreak of Phytophthora in Indiana in 1921. The disease appeared at Lafayette during the first three days of August, 1921. The weather conditions at Lafayette, as given by the U. S. Weather Bureau at Indianapolis, show that for the last three days of July and the first three days of August the mean temperature was 77.5°F. The average maximum temperature for the six days was 86.5°F. which is equivalent to 30.2°C. The average minimum temperature for the six days was 68.5°F. or 20.2°C. The average maximum temperature was very favorable for the maximum development of the fungus, and the average minimum temperature was high enough to permit good growth of the organism. The record of precipitation for the last three days of July and the first three days of August show that on July 30, there was 1.06 inches of rainfall, on August 2, 2.20 inches, and on August 3, 0.85 of an inch, or a total of 4.11 inches for the six days. This is more than the average total rainfall for the entire month of July or August.

From the above data, it is quite evident that temperature and moisture conditions were ideal for the development of the fungus, especially the amount of soil moisture which is undoubtedly the most important of the two factors.

The records further show that the weather conditions for the months of August and September were conducive to the continued development of the disease. The average mean temperature for both months was above normal, and the total precipitation was about double that of the normal for these two months. In August it rained 0.01 of an inch or more on ten different days and 0.01 of an inch or more on twelve different days in September, supplying an abundance of soil moisture at all times.

As previously stated, tomatoes were grown on the same ground in 1922 and no buckeye rot developed. The importance of the soil moisture is again brought out when the records of the U. S. Weather Bureau are consulted. During the months of July, August, and September, 1922, the temperature at Lafayette averaged slightly above normal, but the rainfall for the same months was far below normal, being 0.61 of an inch below normal for July, 1.35 inches below normal for August, and 1.53 inches below normal for September. Thus it can be seen that the most important factor in the development of the disease was lacking in the summer of 1922.

SUMMARY.

A Phytophthora rot of tomato, eggplant and pepper fruits occurred in the field at Lafayette, Indiana, in the late summer of 1921.

The same fungus was repeatedly isolated from diseased fruits, and successful inoculations were secured on eggplant and pepper with the fungus isolated from tomato. Subsequent reisolations from inoculated fruits were made.

The symptoms of the disease on tomato resemble very closely buckeye rot of tomato as described by Sherbakoff, and the fungus agrees mor-

phologically with *Phytophthora terrestris* Sherb., the causal organism of buckeye rot.

Under field conditions, natural infection of immature, uninjured, green tomato fruits occurred.

The lesion on the eggplant fruit was characterized by a conspicuous light border. The fungus grows rapidly in the tissues and causes a browning of the vascular elements and a premature dropping of the infected fruit from the pedicel. Infected peppers also dropped prematurely.

It is possible that the fungus causing the disease may be carried from one locality to another in the soil on the roots of young transplants.

The fungus attains its maximum development at about 30°C. in a humid atmosphere.

The weather records show that the temperature and moisture conditions at Lafayette during the week that the disease first appeared were very favorable for the development of the fungus and that conditions continued to be favorable for the development and spread of the disease.

Tomatoes grown on the same soil in 1922 showed no buckeye rot, probably due to the lack of soil moisture.

DIFFERENCES IN THE SUSCEPTIBILITY OF CLOVER TO POWDERY MILDEW.[1]

E. B. MAINS, Purdue Agricultural Experiment Station.

The powdery mildew of clover has aroused considerable interest this year (1922), because it has been widespread and abundant. This disease has heretofore been rare in America and in consequence the general whitening of clover by mycelium and spores of this fungus has caused more or less alarm among the farmers, from whom numerous inquiries have been received. The disease made its first noticeable appearance in the fall of 1921, and during the spring and summer of 1922 spread rapidly. According to the Plant Disease Survey[2], the mildew first made its appearance upon the first crop of clover in the South, and was first reported from Louisiana, April 10. With the advance of the season, it spread northward and by June 28 was reported in Maine and Minnesota. The writer saw the disease more or less prevalent practically everywhere on his trips through South Carolina, Virginia, Tennessee, Kentucky, Indiana, Wisconsin, and Michigan during May, June, and July. According to the Plant Disease Survey[3], the first record of this disease in the United States was from Prof. Sheldon who reported its inconspicuous occurrence in the vicinity of Morgantown, W. Va., in 1908. In 1915, reports were received from Idaho, Washington, and Oregon, and in 1916 and 1917 from Utah.

There is some question as to the identity of this mildew, since, as far as the writer is aware, no perithecia have been found accompanying the disease, at least in the eastern United States. Miss V. K. Charles (*l.c.* 3) found perithecia on collections from Oregon, Washington, Montana, Colorado, and Idaho, but not from any of the eastern states. Since all clover mildew has been considered as belonging to the species, *Erysiphe Polygoni* D.C., it is very likely that the mildew so prevalent in the eastern United States is this species and that the proper conditions for perithecia formation have not occurred in this region.

Although it is generally agreed that clover mildew has been very severe, there seems to be considerable difference of opinion among pathologists as to the damage caused (*l.c.* 2, 3), some believing very little damage is caused while others believe considerable loss is suffered. The reasons given for attributing loss to this disease, are the death of the lower leaves (Fromme) causing hay to be slightly off color and of poorer quality, the reduction in tonnage by death of lower leaves and also the proportionally higher percentage of stems (Edgerton), and the greater shattering and powdering of the leaves in hay from diseased fields (Elliot). This is one of the diseases of plants for which it is hard to obtain any accurate estimate since it does not kill the plants attacked nor reduce the yield to such a marked extent but that the loss

[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

[2] U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 1, pp. 8-14. 1922.

[3] U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 3, pp. 53-55. 1922.

can be attributed to weather conditions. However, it hardly seems possible that fields can be so thoroughly infected with a disease that they "look as if they had been heavily dusted with flour" (Edgerton) and "when the mower goes through the field a white cloud arises on all sides" (Anderson) without the fungus interfering considerably with development and yield of its host. Not only must considerable food be withdrawn from the host by the parasite but also the mat of mycelium on the surface of the leaves and the haustoria within the cells must interfere considerably with photosynthetic activities of the plant and thus prevent, to a more or less extent, the manufacture of the plant's food. The withdrawal of food and the weakening of the plant undoubtedly brings about the premature death of parts of the plant such as the older, longest-infected leaves but not so rapidly but what new leaves take their place, which in turn gradually are infected. However, the plant as a whole is probably very seldom if ever weakened so much as to succumb entirely except after prolonged attack. In the absence of destruction or serious weakening of all or part of the crop, there is no good basis for measuring loss since the widespread occurrence of the disease precludes the opportunity of comparing diseased and disease-free fields of like fertility, and otherwise comparable. As indicated above, the enormous mycelial and spore production must reduce to some extent the stored food of the clover plant and correspondingly its feeding value. The premature death of the older leaves and possible increased shattering of the diseased younger leaves is another source of loss. If the second crop of clover is saved for seed, possibly the loss may be more easily measurable since with the lowered food content of the clover plant there is likely to be a reduction in the number or quality of seed matured.

A matter of considerable concern to the farmers is whether mildewed clover is fit for feed. From the evidence furnished by the Plant Disease Survey (*l.c.* 2) no harm is liable to result from feeding such clover. Hesler reports that tests conducted by the Tennessee Experiment Station indicate that stock (horses, cattle, sheep, swine) is not injured after being fed or grazed 14 days on mildewed clover. Edgerton reports that no poison or injurious substance is formed. Dungan quotes C. M. McWilliams, Farm Adviser of Randolph County, Illinois, who observed no ill effects from feeding the mildewed clover to cattle, horses, and mules. There is a possible slight danger in feeding the hay to horses on account of the presence of the spore-dust. Tehon reports a trouble in cattle similar to 'heaves' attributed to mildewed clover in southern Illinois.

Control of a disease of the nature of mildew under the cultural conditions necessary for clover is extremely difficult, and apparently the only feasible method is in the discovery or development of disease-resistant strains. The biology of the mildew of clover, however, has not been extensively studied. Salmon[4], upon a morphological basis, considers the mildew of clovers as *Erysiphe Polygoni* DC. for which he gives 359

[4] Salmon, Ernst S. A Monograph of the Erysiphaceae. Mem. Torrey Bot. Club. 9:1-292. 1900.

species belonging to 154 genera as hosts. He gives the following species of clover as hosts: *Trifolium agrarium, T. alpestre, T. arvense, T. filiforme, T. hybridum, T. incarnatum, T. involucratum, T. longipes, T. lupinaster, T. medium, T. minus, T. monanthum, T. montanum, T. moranthum, T. pauciflorum, T. pratense, T. procumbens, T. repens,* and *T. rubens.* That *E. Polygoni* must consist of a large number of specialized races is indicated by the researches of Neger and Salmon[5], the former being unable to infect *Trifolium repens, Vicia sepium* or *Hypericum montanum* with conidia from *T. incarnatum,* and the latter finding that the mildew from *T. pratense* would not infect *T. agririum, T. repens, T. medium, T. montanum, T. incarnatum, T. filiforme, Lotus corniculatus, Melilotus arvensis, Medicago sativa, Lupinus lutens* or *Pisum sativum,* but infected *T. pratense* heavily. According to this, the mildew on *T. pratense* is a race restricted to that species of clover. Likewise the mildew on *T. incarnatum* represents another closely restricted race. Observations by various pathologists during the past year as reported in the Plant Disease Survey agree with these results.

There are evidently few or no observations upon varietal or individual differences in the reaction of *T. pratense* to the specialized race of mildew which exists on it. Dr. A. J. Pieters (*l.c.* 2) has observed at Arlington, Virginia, that many of the American varieties of red clover were affected while most of the European strains were free or nearly so. In the fall of 1921, the writer noticed that considerable differences existed between the species of Trifolium as to susceptibility to mildew, and also that similar differences were to be found between varieties of *T. pratense.* The plants upon which these observations were made were started in pots of sterilized soil in the greenhouse and were transplanted to the field in late summer. The plants were set about ten inches apart in rows two feet apart, so that there was no difficulty in observing individual differences. By October 13, when notes were taken, the plants were well established and in good condition. The notes given in the following table represent the reaction of individuals and varieties under field conditions to natural infection of the powdery mildew.

[5] Salmon, Ernst S. On Specialization of Parasitism in the Erysiphaceae. Beihefte Bot. Centralbl. 14:261-315. 1903.

TABLE I. Susceptibility of Clovers to Powdery Mildew in the Field, Lafayette, Ind., October 13, 1921.

Species and Variety	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility—No. Plants			
			Heavy	Moderate	Slight	None
Trifolium pratense 2019*	South Dakota	44	13	22	9	
Trifolium pratense 2020	Ohio	44	9	15	19	1
Trifolium pratense 1809	North Dakota	9	2		7	
Trifolium pratense 2055	Chile	17		1	16	
Trifolium pratense 1819	Italy	10			8	2
Trifolium pratense	France	44			15	29
Trifolium pratense 43592	England	10				10
Trifolium incarnatum 2054		10				10
Trifolium hybridum 2047		12				12
Trifolium repens 48625	Holland	8				8
Trifolium repens 1928	Wisconsin	10				10
Trifolium repens 1912	Idaho	25				25
Trifolium repens 48019	England	12				12
Trifolium subterraneanum 51212		10				10
Trifolium fragiferum 29012		12				12
Trifolium reflexum 03308		12				12

*Numbers following names are those used by the Office of Forage Crop Investigations, U. S. Dept. Agriculture.

Encouraged by these results, further work was started this past summer (1922). Seed of 17 varieties of clover grown on the Experiment Station farm at Lafayette, Indiana, were sown in individual flats of sterilized soil in the greenhouse. About midsummer the mildew showed up and spread fairly rapidly. In order that all the flats might be uniformly inoculated, they were dusted with the mildew the latter part of November, atomized and kept covered with moist cloths for several days. The mildew developed rapidly and by the first of December the older leaves of a number of the varieties were white with the mycelium and spores. The plants were then taken from the flats, sorted according to susceptibility, counted and the immune and highly resistant plants were transplanted. The varieties tested and the results obtained are given in table II.

TABLE II. Susceptibility of Varieties of Red Clover, *Trifolium pratense* to Mildew, in Greenhouse Tests. December 1, 1922.

Varietal No.	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility, No. Plants		
			Heavy	Moderate —Slight	None
2135	Ohio	206	151	39	16
2138	Tennessee	133	90	30	13
2148	Oregon	117	45	55	17
2203	Chile	113	12	88	13
2217	Chile	129	43	68	18
2142	Chile	130	25	73	32
2055	Chile	138	28	67	43
2218	North Germany	230	34	129	67
2214	Hamburg	128	7	55	66
2121	Bohemia	221	1	109	111
2219	Hungary	215	7	147	61
2202	France	127	6	87	34
54456	France	140	15	73	52
54493	France	127	10	76	41
54492	Italy	153	9	95	49
54779	Italy	139		68	71
2212	Italy	168	3	95	70

An examination of table I shows that, among the various species of Trifolium represented, only *T. pratense* was mildewed. *T. incarnatum*, *T. hybridum*, and *A. repens*, all of which are given as hosts for *Erysiphe*

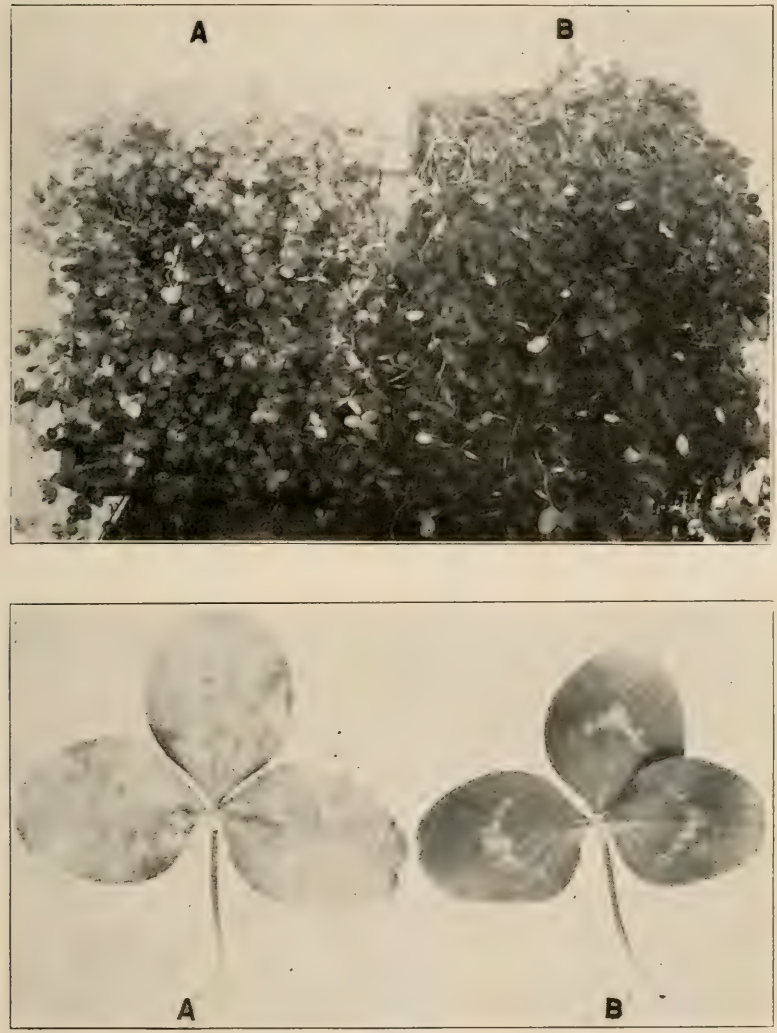

Fig. I. Difference in Susceptibility to Mildew. (A and B.) Difference in Two Clover Varieties. A. Flat of Tennessee 2138 clover susceptible to mildew. B. Flat of Italian 54779 clover resistant to mildew. (A′ and B′.) Difference in Two Plants of Variety Ohio 2135. A′. Leaf of susceptible plant. B′. Leaf of immune plant.

Polygoni, were absolutely free from mildew. This, therefore, would agree with the results of Salmon as well as the observations of a number of pathologists in this country in 1922 that the mildew of red clover

is restricted to that species. However, not all of the varieties of *T. pratense* were found to be susceptible. An examination of tables I and II shows an interesting situation, the North American varieties being generally quite susceptible, while the European show in general rather high resistance. The Chilean seemed intermediate between the two. Figure I (A and B) shows the difference in susceptibility shown by a flat of the variety Tennessee 2138 and a flat of the variety Italian 54779.

What the significance of this situation may be, is hard to say. It is possible that the long presence of mildew in Europe may have had a selective effect, possibly preventing the formation of seed in susceptible plants. This would necessitate a very marked effect of the mildew on seed production. On the other hand, the absence of mildew in this country would preclude any such selection. However, as far as the writer has been able to determine, no one has noted red clover resistant or immune to mildew in Europe. On the other hand, judging from the lack of comment on the disease, it may not be serious at the present time, possibly indicating resistance but not complete immunity. It is useless, however, to theorize until we have a better knowledge concerning the biology of this disease and the relation of the race on *T. pratense* to a greater number of other species of Trifolium, especially native wild species, and until we know whether differences exist between the mildew in North America and Europe in its ability to attack varieties, whether the mildew in this country has been recently introduced or whether climatic conditions of the past year have been responsible for the development and conspicuous appearance of the disease, and what the effect is on the clover plant, especially upon seed production.

Another thing noticeable in tables I and II is the presence of resistant individuals in all except three of the varieties tested. It is likely that if a larger number of plants of these three had been tested, resistant plants would also have been found among them. Figure I (A′ and B′) shows a leaf from a susceptible and a leaf from a resistant plant of Ohio 2135.

As we have already noted the discovery or development of resistant varieties suggests the most likely control. Unfortunately in most cases the presence of one or more undesirable qualities in resistant varieties complicates the situation. Thus several of the resistant European varieties apparently are not especially adapted to our climate, since those in the field during the comparatively mild winter of 1921-1922 winter killed badly. Prof. A. T. Wiancko[6] has stated that in his field tests of clover varieties, the Italian killed out entirely during the winter of 1920-1921. In consequence it appears very doubtful if these varieties would be of much value except for hybridizing work. Unless other European varieties prove to be hardy, the most promising method of obtaining mildew-resistant strains appears to be by the selection of resistant individuals in American varieties.

[6] Wiancko, A. T. Report of the Director, Purdue University Agricultural Experiment Station. 1921:37.

TABLE III. Source of Seed and Its Bearing on Winter Injury.

Condition of Varieties of *Trifolium pratense*, Spring, 1922

Varietal No.	Original Source of Seed	Condition—No. of Plants		
		Good	Poor	Dead
2019	South Dakota	30	6	8
2020	Ohio	33	4	7
1809	North Dakota	7	1	1
2055	Chile	3	7	7
1819	Italy		1	9
	France	3	11	30
43592	England		1	9

SUMMARY.

1. The mildew of red clover, *Trifolium pratense*, is apparently specialized on that host, crimson, *T. incarnatum*, Alsike, *T. hybridum*, and white, *T. repens* not being infected.
2. Considerable differences exist between varieties of red clover as to susceptibility to the mildew, American varieties being much more susceptible than European.
3. Resistant individuals are probably to be found in all varieties, the number varying with the variety.
4. Selection and breeding for resistance offers the best means for controlling the disease.

The writer wishes to acknowledge his indebtedness to Dr. A. J. Pieters, Office of Forage Crop Investigations, U.S. Dept. of Agriculture, and Mr. R. R. Mulvey, Soils and Crops Dept., Purdue Agricultural Experiment Station, for furnishing the seed of clover varieties upon which this work was done.

THE PRESENT STATUS OF THE HOT WATER TREATMENT IN INDIANA.[1]

C. T. Gregory, Purdue University Agricultural Experiment Station.

The first application on the farm of the hot water treatment of wheat for the control of loose smut was made in Indiana in 1917 by six men in five counties. Since that time the number has steadily increased until in 1921 there were about 850 farmers in 50 counties who treated their wheat. Moreover, the influence of the treatment has been spread by the ever increasing supply of seed from treated fields. For example, in Shelby County, where some of the pioneer work was done, there is a supply of 25,000 bushels of such seed this year (1922); Hancock County has over 2,000 bushels; Gibson County, 3,000 bushels; Posey County, 5,000 bushels; and Wayne County, 4,900 bushels. It is reported that there are 29,000 acres in Knox County planted with seed from treated fields.

As is usual when a laboratory control method is first applied on the farm many unforeseen changes were necessary to make the method entirely practical. The particular changes that have been made can best be discussed under the different phases of the treatment.

1. *Presoaking.* It has been proven that presoaking is one of the essential steps in the treatment. The early recommendation, to soak the wheat in cold water for eight hours, is perfectly proper but under farm conditions this time is too long because the treating usually begins about 9 A.M. making it necessary to begin soaking the seed at 1 A.M. Investigations showed that four hours presoaking was sufficient and that 12 hours soaking is dangerous because the seed is quite apt to germinate and thus be rendered much more susceptible to injury by the treatment to follow. A peculiar mistake in the presoaking recommendations was made in Porter County last year. The farmers thought that any four hours previous to treatment would do and they soaked the wheat during the previous afternoon. Promptly at the end of the time they removed the sacks from the water but allowed the soaked wheat to stay in the sacks until the following morning thus permitting sufficient germination to prevent successful treatment.

Not more than one bushel of dry wheat should be soaked in a two bushel burlap sack because it swells to almost twice its original bulk. If the sacks are too full the seed will soon become packed and either burst the sacks or, as sometimes occurs, the tight outer layer excludes the water and the wheat in the center is not properly soaked. Because of this propensity of the seed to swell and tightly pack, the sack should be laid on its side in the water, rather than on end.

2. *The Treatment.* At first a half bushel of wheat was treated in a barrel of hot water, the temperature being maintained by adding boiling water from time to time. In Shelby County where large amounts of wheat were treated this method was too slow and a rather ingenious

[1] Contribution from the Department of Botany (Extension Division) of the Purdue University Agricultural Experiment Station.

"Proc. 38th Meeting, 1922 (1923)."

device was made to meet the emergency. It consisted of a heavy wire drum holding five bushels of soaked wheat, which revolved in a large tank of water heated by steam. This is distinctly a field application of the treatment. However, the sack method is still frequently employed, but instead of barrels, large tanks of water heated by steam are used so that six to eight men may treat their wheat at one time.

A device which enables the operator to keep the wheat in the hot water without burning his hands consists of loops of heavy twine fastened by a slip-noose to the mouth and one corner of the sack. It has been noted that grain sacks are unsatisfactory for treating because the tightly woven cloth seems to prevent the ready passage of the water through the wheat, and burlap sacks are therefore recommended. When using the drum not more than five bushels of wheat should be treated at once and the drum should not be filled more than two-thirds full. This allows a free movement of the wheat and a quick and thorough mixing with the hot water.

The time of treating and temperature of the water have not undergone any change. Temperatures as high as 135 F. will not injure wheat, and it is also known that immersion in water at 130°F. for 15 minutes will not do any particular harm to the seed. However, these facts are only used as leeway in the treatment rather than as changes because it is necessary to speed up the treatment as much as possible and there is usually nothing to be gained in lengthening the time of treatment.

3. *Drying the seed after treatment.* Perhaps the greatest drawback to the treatment is the drying of the seed. It has been found, however, that it is only necessary to surface-dry the grain so that it will run through the drill without clogging. Allowance is made for the swollen condition of the grain by setting the drill to sow about twice as much as customary. Experiments at Washington, D.C., have shown that wheat can be dried very thoroughly in artificial dryers without injury to seed. One illuminating incident happened this year in Clinton County. Some treated wheat remained wet too long after treatment and produced sprouts that were in some cases a quarter of an inch long. A sample of this seed was dried completely over a radiator and sent to Purdue to be tested. It germinated 92.5 per cent.

Results. Usually the stand of the treated wheat is thin but the plants stool much more than the untreated wheat so that the final number of heads produced is about the same in both cases. It has been noticed generally that the heads in the treated wheat are much more uniform in size and are usually somewhat larger than in the untreated. It is possible that the thinning of the stand may have something to do with this but it is believed that the treatment kills the weak seed and that only the stronger plants survive. This belief is supported by the fact that the improvement in the crop usually maintains itself in the wheat the second and third year after treatment.

The treated wheat will usually ripen about a week later than the untreated wheat, but this is not an objectionable feature. This delay in ripening did, however, result rather disastrously in Bartholomew County two years ago. The weather was apparently unfavorable during

the time of filling and ripening and since it had a week more to act on the treated wheat the grain was considerably shrivelled and really inferior to the untreated wheat. The farmers blamed the treatment for the trouble.

It was noticed at first that certain weeds like cockle and rye would often be killed by the treatment. This led to rather false hopes for the treatment and some county agents went so far as to recommend the hot water treatment as a means of ridding the wheat of cockle. We have found, however, that this cannot always be depended upon. In Posey County it has been found that a treatment of 15 minutes at 130°F. is more effective in killing cockle and that it will not materially injure the wheat more than the ten minute treatment. Experiments in treating cockle seed have shown that one controlling factor is the length of time that it is presoaked. With the cockle seed used, it was found that after 12 to 24 hours of soaking the germination was reduced very materially by the treatment. It seems, too, that fresh cockle seed is more susceptible to injury than old seed.

Without question the treatment will control the loose smut but there are certain factors which have been found to prevent a perfect control. These are: 1. Insufficient presoaking of the seed; 2. Imperfect heating of the seed due to excessive amounts of wheat in the sack or the drum; 3. An incorrect thermometer, registering too high so that the actual temperature of the water was below 129°F. The stinking smut, however, is not always controlled. This is apparently due to the inability of the heat to kill the spores in the center of the smut-filled seed, followed by the subsequent breaking of these spore masses, which results in the distribution of viable spores over the wheat. In Porter County in 1922 there was one field where the treated wheat had 10 per cent of stinking smut and the untreated part about 12 per cent.

Changes made in the field applications. The original recommendation for eradication of loose smut, given by Freeman and Johnson in bulletin 152 of the Bureau of Plant Industry, and at first followed in Indiana, was as follows: Treat enough wheat for a small seed plot, about five bushels, and select the seed for the next year's crop from this plot. The first objection to this program came from the farmer. He could not or would not keep this small area separate from the rest of the wheat. Usually it was necessary to plant this patch in a larger field and when it came to cutting this separately and hauling it to the threshing machine separately the trouble began. The farmers who had been convinced of the value of the treatment treated enough seed for a whole field and supplies of supposedly smut-free wheat began to appear. With the advent of wheat certification, which calls for practically smut-free wheat, the treatment became more popular. It soon became evident, however, that using wheat from a smut-free field did not guarantee a smut-free crop owing to the fact that the spores could easily be blown from neighboring or even distant fields. This showed the fallacy of recommending the seed plot method or even separate fields of treated wheat and also seems to be one of the factors which has been retarding the spread of the practice. The farmers feel that it is useless to treat

a small amount of seed if the wheat produced is liable to give a badly diseased crop the next year.

Another old idea which has acted against a wider application of the treatment has been that the farmers themselves can not handle the treating because it is too complicated and dangerous. The whole treating project is being revised this year. It has been demonstrated in Knox and Shelby counties that a widespread use of treated seed will greatly reduce the dangers of the spread of the smut. In Knox County it was found last summer that wheat which had been treated last year had no smut in it; that which was one year from treatment had no smut; two years from treatment there was one-quarter per cent; and three years from treatment two per cent while in the untreated fields there was an average of eight per cent. This shows rather clearly that the best way to handle this problem is to establish smut-free areas or communities. In order to do this it is evident that the actual treating in a large area would soon become too great for one station to handle. This was solved by placing the treating stations in the hands of the farmers themselves. Five groups of farmers in Clinton County, three groups in Marion County and one group each in Henry and Wabash counties treated a total of over 800 bushels. In every case enough seed was treated to plant a whole field and so far as the treatment itself was concerned the work of these farmers was a complete success.

The steps in advance that have been made are these:

1. Enough seed is being treated for whole fields so that it will be much easier to keep this wheat separate and propagate the seed.
2. The farmers themselves are beginning to handle the treatment and in this way greatly increasing the number of centers from which the treated wheat can start.
3. Smut-free areas are being established in which it is hoped that wheat can be maintained free from loose smut for several years.

ONION SMUT IN INDIANA.[1]

C. T. Gregory, Purdue University Agricultural Experiment Station.

A survey of all the important onion growing regions of Indiana in 1922 showed the smut disease to occur abundantly in Lake County, around Munster, and in one locality near Rensselaer in Jasper County. In the vicinity of Munster there is a considerable industry in the growing of onion sets and in these fields the disease is very severe, frequently causing losses of 50 per cent or more. The losses caused are of two types, a direct loss by the destruction of the plants and indirectly by the production of over-sized onions which are often discarded as they are not salable as sets. These over-sized onions are the result of a thinning of the stands by the disease permitting the onions that remain to grow more than is desired. In addition, it has been found that the

[1] Contribution from the Botanical Department (Extension Division) of Purdue University Experiment Station.

shrinkage in storage of the onions grown in infested fields is very much greater than in those from uninfested fields or from formaldehyde treated seed.

It has been proven beyond a doubt that the formaldehyde "drip" method of treatment will control the onion smut very effectively but the method was designed to apply to onions that are sown at the rate of five to seven pounds per acre. In Lake County, where the seed is sown at the rate of about 60 pounds per acre, the problem is somewhat different. Under these conditions the control is never 100 per cent but it has been sufficiently effective to secure its adoption by the majority of growers. The probable explanation of the control by the formaldehyde treatment is that the gas evolved disinfects the soil in the immediate vicinity of the seed through which the seedlings must grow thus killing the spores or the saprophytic mycelium. This disinfecting action does not seem to extend over a sufficient area to permit the large number of seedlings developed in the row to grow in disinfected soil and as a result a small proportion of the plants may be diseased. This may possibly be explained by the fact that the formaldehyde does not wet an area more than three-quarters of an inch wide, though the gas may spread somewhat beyond this, whereas the row of onion seedlings is about an inch and a quarter wide.

Aside from the failure of the formaldehyde to completely disinfect the soil there are other factors that seem to affect the efficiency of the treatment. The growers believe that spring plowing so loosens the soil that the formaldehyde penetrates too deeply for proper or sufficient disinfection. The amount of rain at planting time and immediately following is very important. In 1921 the heavy continuous rains at the time of treatment, and during the week following, practically nullified all the beneficial effects. The probable explanation of this fact is that the rain diluted the disinfectant so that it lost its potency, or else the presence of the water in the soil prevented uniform penetration.

The usual recommendation for dilution is one pint of 40 per cent formaldehyde in 16 gallons of water, to be used at the rate of 200 gallons per acre.

The treated onions had about five per cent of smut while the untreated parts of the beds averaged about 50 per cent. Increases in yields of 100 bushels per acre were obtained.

The growers at Munster found that they were usually applying only 140 to 160 gallons so it was decided to dilute the formaldehyde, one pint in 10, 12, and 14 gallons of water. This was done in 1922 with somewhat better control of the smut and without causing any injury to the seedlings. Rather peculiar results were obtained, however, from the treatment. The soil at the time of sowing was dry and the weather very favorable for the treatment. An examination of the fields in June showed the treated rows had less than five per cent of smut while the untreated rows had as much as 95 per cent in some cases. In one field where the grower did not use the treatment, over half of the plants were being destroyed by the smut. During the summer there were no effective rains and the temperature was generally above normal. These

abnormal conditions had a particularly harmful effect in the treated rows while the untreated rows were apparently not so seriously affected. The results of some of the growers are as follows: Joe Munster, who treated all his seed, reports that he did not harvest the crop because it was a complete failure. John DeVries did not get any difference in yield between his treated and untreated fields. Andrew Krooswyk states that his treated seed was somewhat better than the untreated but neither was worth much. In other words, the treatment did not seem to have had the beneficial effects obtained in previous years.

The explanation of this trouble seems to be that the treatment permitted a heavy growth of onions whereas the untreated areas were very much thinned by the smut. The continued dry weather so depleted the soil of water that in the heavy, normal stands the plants were unable to make any growth and as a result most of the bulbs did not develop. On the other hand, there was not so much competition among the plants of the diseased (untreated) rows and the few that remained were able to get sufficient moisture to develop small bulbs which were just the right size for sets. This resulted in approximately the same yields in the treated and untreated onions. Viewed in connection with previous experiences and from all angles, this peculiar and unexpected effect is really an argument for the treatment since it shows that smut control permits a much thicker stand which in normal years would produce an almost perfect yield.

THE MAKING OF GENERA IN FUNGI.

J. M. Van Hook, Indiana University.

The question of genus making and what it takes to constitute a genus, has provoked much discussion from the earliest times and we are now possibly no nearer its solution than before, possibly farther away.

The object of this brief paper is to present one point of view and one which is very apparent even to the youngest student of systematic mycology. It occurs to the student that genera are often erected for convenience and for the convenience of analytic keys rather than for any great scientific differences in their characteristics. He often finds genera widely separated in sequence in texts, when in reality they may possess only a single slight difference and this difference may not be constant among the various species of the genera. As an illustration of the above, we may cite the case of Pleurotus and Claudopus among the Agaricaceae. The chief difference between these two genera seems to be that of spore color. This single difference, and we have many such genera, necessitates a separate genus because of a major division of the family based upon spore color. The specimen at hand whether it be a Pleurotus or a Claudopus, may be traced through the key to exactly the same place except as to spore color. When, however, one tries to classify such a well recognized species as *Pleurotus sapidus* Kalchbr., he will likely refer it to the genus Claudopus on account of the beautiful light grayish vinaceous spores in mass. These so-called pink spores will retain their color for many months in a strong light. However, after a study of the very similar oyster agaric, *Pleurotus ostreatus* Fr., one can scarcely make a separate species out of *P. sapidus*, much less a genus. Certainly it belongs to the pink-spored group as far as spores are concerned, although no one of experience would consider it a Claudopus.

In the group of Ascomycetes, we find the genus Rosellinia widely separated from Hypoxylon by certain mycologists on account of the separate perithecia of the former and the stromatic perithecia of the latter. Yet even a superficial study of the family Xylariaceae will display Rosellinia forms whose perithecia coalesce and Hypoxylon forms whose perithecia are separate. Where such forms occur, we have Rosellinias that are apparently Hypoxylons and Hypoxylons that are apparently Rosellinias. If broader and better characters had been chosen on which to base the above genera, this confusion would not occur and these closely related genera would not be placed in widely separated families. In view of the remarkable similarity of the species of these genera, as to habitat, external appearance and spores, we see scarcely more than a subgeneric difference at the most. Saccardo seems to be one who did not fall into the usual error and used a system based upon spore-color which happens to place Rosellinia where it rightfully belongs.

In this same family (Xylariaceae), we notice the closely related genera, Nummularia, Hypoxylon and Daldinia. The globose forms of

"Proc. 38th Meeting, 1922 (1923)."

all three are almost identical and have similar spores. While one of the chief generic characteristics of Daldinia is the concentric layers of its stroma, we have a rather common species of Hypoxylon whose most noticeable characteristic is that of concentric stromatic layers. It follows that a student learns these similar fungi as individuals rather than by following a key to genera and species. Concerning Nummularia, Ellis and Everhart say: "The genus is too closely allied to Hypoxylon, especially the discoid forms."

Among the imperfect fungi, a group in which the writer is particularly interested, genera seem to have been formed for convenience in many cases and we have been led into species multiplicity and countless errors.

As an example, we cite the common genera, Phyllosticta, Phoma and Macrophoma. When the first two were set apart, their only difference was that of habitat. If on a leaf, it was Phyllosticta; if on any other part of a plant, it was a Phoma. When one considers the similarity of a young shoot and a leaf, he wonders why such a division was ever made. Furthermore, those species of the genus Phoma having spores more than fifteen microns long, were placed in a separate genus, Macrophoma, this arbitrary difference in spore length sufficing for a new genus.

The entire group of imperfect fungi abounds in similar examples. In the Hyphomycetes, the group with scattered and tufted conidiophores is separated into the families Mucedinaceae and Dematiaceae entirely on the basis of mycelium color, yet this basis was not used in separating the Stilbaceae and Tuberculariaceae.

It is to be noted also that genera have been based upon spore shape. In the classification group known as Scolecosporae, a spore must be long in proportion to its width. But just what proportion? While a standard of proportion may be attained by long study of the groups, the actual determination, left to the individual, has resulted in the placing of those fungi with spores of intermediate proportion in the group which suits the judgment of the individual. As a result, a student must search through several genera to locate his plant. A spore size limit as in the case of Phoma and Macrophoma would be preferable.

The common practice of forming sub-groups of any kind for the purpose of classification where the groups are large and unwieldy, has in many cases, resulted in the establishing of many doubtful or peculiar genera.

NOTES ON MICROTECHNIQUE II.

M. S. Markle, Earlham College.

The damage done to recently mounted microscopic slides by a class of freshmen is well known; yet is it often impossible to anticipate one's needs sufficiently to allow time for slides to harden. This is especially true of slides mounted in Venetian turpentine, which hardens more slowly than balsam. I have found that slides may be used at once, after being mounted according to the following method.

The Venetian turpentine into which the material is finally brought is allowed to dry until it is quite hard—so thick that its surface may be indented with difficulty. This is softened by being placed on a warming-plate. The material when sufficiently warmed to be thin enough for ready mounting is placed on the slide on another hot-plate, the material is arranged with needles, a cover is added and the material allowed to fill the space under the cover.

With a little more care, stem sections, and even paraffin sections may be mounted in balsam in the same manner. I have been much surprised to find what extreme temperatures sections will endure without damage. By accident, some slides of *Marchantia* antheridia were mounted and left on a hot-plate 22 hours. I supposed they would be ruined, but careful examination showed no damage. A thermometer placed on the hot-plate showed a temperature of 145° C.

A convenient hot-plate for such work or for stretching paraffin ribbons or for warming imbedding-dishes while the pieces of material are being arranged may be made by mounting an ordinary electric bulb inside a box over which a piece of glass has been placed. A discarded photographic negative is satisfactory. For higher temperatures, a piece of zinc or sheet brass is better. Temperatures may be modified by varying the wattage of the electric bulb used. Very high temperatures may be gotten by mounting the bulb vertically and placing over it a tin cylinder covered with asbestos paper. A thin lantern slide plate was used for several weeks over the hot-plate mentioned above as giving a temperature of 145° C. without breakage.

I have been using with great satisfaction the gelatin-glycerin fixative described in the Botanical Gazette, April, 1919, by Artschwager. I use phenol instead of sodium salicylate. The results are superior to those obtained by the use of egg albumen.

Even with the best of fixatives, some materials persist in coming off the slide during the staining-process, especially when aqueous stains, such as the haematoxylins, are used. Following a suggestion by Dr. F. D. Lambert, of Tufts College, I have used with excellent results the following method. After the paraffin has been dissolved in xylol and the xylol has been removed with alcohol, the slides are dipped in a very weak solution of celloidin in alcohol and ether. The slides are removed, allowed to drain but not to dry and are carried through the staining-process in the usual way. Celloidin stains heavily in haematoxylin, but by the time the destaining is completed, no trace of the stain remains in

"Proc. 38th Meeting, 1922 (1923)."

the celloidin. In this way I have saved thousands of slides that would otherwise have been lost. Small structures, such as spores, starch-grains, and the like, are readily retained in the sections.

Recently in mounting some epidermis of tulip for the study of stomata, I noticed that many of the nuclei of the epidermal cells were dividing amitotically. Many stages could be observed in a single field of view. I do not know how commonly this may be found in tulip epidermis, but the material described is the best I have seen for the demonstration of amitasis.

CONSTITUTION AND BY-LAWS

INDIANA STATE ACADEMY OF SCIENCE.

CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other sources and riches of the State; to arrange and prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

WHEREAS, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members, and active members.

SEC. 2. Any person engaged in any department of scientific work, or in any original research in any department of science, shall be eligible to active membership. Active members may be annual, life members or patrons. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Any person who shall at one time contribute one hundred dollars to the funds of this academy may be elected patron, who shall be a life member of the Academy, free of dues. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Application for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary, Editor, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of the Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past President, together with the officers and Executive Committee, shall constitute the council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

8. An Editor shall be elected from year to year. His duties shall be to edit the annual Proceedings. No allowance shall be made to the Editor for clerical assistance on account of any one edition of the Proceedings in excess of fifty ($50) dollars, except by special action of the Executive Committee.

Geographic Distribution of Members. Marion County, 9 fellows and 74 active; Tippecanoe, 11 fellows and 66 active; Monroe, 18 fellows and 39 active. Thirty-nine of the 92 counties are represented and 22 of the 39 have only one member.

MEMBERS.[1]

FELLOWS.

Andrews, F. M., 110 E. Tenth St., Bloomington	1896[2]	1911[3]
Arthur, Joseph C., 915 Columbia St., Lafayette	Charter	1893
Badertscher, J. A., 312 Fess Ave., Bloomington	1914	1917
Beede, Joshua S., 200 Seneca St., Bantesville, Okla.	1902	1906
Behrens, Charles A., 217 Lutz Ave., W. Lafayette	1916	1917
Bennett, Lee F., 309 S. Ninth St., Janesville, Wis.	1898	1916
Benton, Geo. W., 100 Washington Sq., care American Book Co., New York, N.Y.	Charter	1896
Bigney, Andrew J., Evansville College, Evansville	Charter	1897
Blanchard, William M., DePauw University, Greencastle	1909	1914
Blatchley, W. S., 1558 Park Ave., Indianapolis	Charter	1893
Breeze, Fred J., State Normal, Muncie	1898	1910
Bruner, Henry Lane, Butler College, Indianapolis	1892	1899
Bryan, William Lowe, Indiana University, Bloomington	1893	1914
Butler, Amos W., 52 Downey Ave., Irvington, Indianapolis	Charter	1893
Carr, Ralph H., Purdue University, Lafayette	1914	1922
Cogshall, W. A., 423 S. Fess Ave., Bloomington	1905	1906
Coulter, Stanley, 213 S. Ninth St., Lafayette	Charter	1893
Culbertson, Glenn, Hanover College, Hanover	1895	1899
Cummings, Edgar Roscoe, 327 E. Second St., Bloomington	1900	1906
Deam, Charles C., Bluffton	1900	1910
Dietz, Harry F., State Conservation Commission, Indianapolis	1909	1922
Dryer, Charles R., 325 Grove St., Ft. Wayne	Charter	1897
Dutcher, J. B., 1212 Atwater Ave., Bloomington	1907	1915
Eigenmann, Carl H., 630 Atwater Ave., Bloomington	Charter	1893
Enders, Howard E., 249 Littleton St., West Lafayette	1906	1912
Evans, Percy Norton, 302 Waldron St., West Lafayette	1895	1901
Fisher, Martin L., 325 Vine St., West Lafayette	1908	1919
Foley, Arthur L., Indiana University, Bloomington	1894	1897
Hessler, Robert, 25 S. Bolton Ave., Indianapolis	Charter	1899
Hufford, Mason E., 514 S. Sluss Ave., Bloomington	1904	1916
Hurty, John E., 31 E. Eleventh St., Indianapolis	1902	1910
Hyde, Roscoe Raymond, 4101 Penhurst Ave., Baltimore, Md.	1909	1909
Jackson, Herbert S., Agricultural Exp. Station, Lafayette	1915	1919
Kern, Frank D., Dept. of Botany, State College, Pa.	1905	1912
Koch, Edward W., 24 High St., Buffalo, N. Y.	1914	1917
Logan, Wm. N., 924 Atwater Ave., Bloomington	1916	1917
Mahin, Edward G., Purdue University, Lafayette	1902	1922
Markle, M. S., Earlham College, Earlham	1910	1919
McBeth, Wm. A., 1905 N. Eighth St., Terre Haute	Charter	1904

[1] Every effort has been made to obtain the correct address of each member. In order to keep the mailing list correct, it is necessary that the secretary be informed of all changes of address. In accordance with the action of the Academy, members two years in arrears have been dropped from the roll.

[2] Date of election to Academy.

[3] Date of election to fellowship.

McBride, Robert W., 1239 State Life Bldg., Indianapolis..Charter 1916
Middleton, Arthur R., 705 Russell St., W. Lafayette..... 1906 1918
Moenkhaus, W. J., Indiana University, Bloomington..... 1893 1901
Mottier, David M., 215 Forest Place, Bloomington.....Charter 1893
Naylor, Joseph P., Greencastle.....Charter 1903
Nieuwland, J. A., Notre Dame University, South Bend..... 1908 1914
Payne, F., 620 Ballantine Road, Bloomington..... 1913 1916
Ramsey, Rolla R., 615 E. Third St., Bloomington..... 1904 1906
Rettger, Louis J., 31 Gilbert Ave., Terre Haute..... 1893 1896
Rothrock, David A., 1000 Atwater Ave., Bloomington..... 1898 1906
Scott, Will, Indiana University, 525 S. Park St., Bloomington 1905 1914
Shannon, Charles W., 518 Lahoma Ave., Norma, Okla.....Charter 1912
Smith, Charles Marquis, 152 Sheetz St., West Lafayette.... 1910 1912
Stoltz, Charles, 311 W. Jefferson Blvd., South Bend..... 1909 1919
VanHook, James M., 639 N. College Ave., Bloomington.... 1909 1911
Wade, Frank Bertram, Shortridge High School, Indianapolis 1903 1914
Weatherwax, Paul, 416 S. Dunn St., Bloomington..... 1913 1922
Williamson, E. B., Bluffton..... 1911 1914
Wright, John S., care Eli Lilly & Co., Indianapolis..... 1893 1894

NON-RESIDENT MEMBERS AND FELLOWS.

Abbott, G. A., Grand Forks, N.D., Fellow.....1908[4]
Aldrich, John Merton, Washington, D.C., Fellow.....1918
Brannon, Melvin A., Beloit, Wis.[5]
Burrage, Severance, Denver, Colo., Fellow.....1898
Campbell, D. H., Stanford, Cal.[5]
Clark, Howard Walton, U.S. Biol. Station, Fairport, Iowa.....1900
Cook, Mel T., New Brunswick, N.J., Fellow.....1902
Coulter, John M., University of Chicago, Illinois, Fellow.....1893
Davis, B. M., Oxford, Ohio.[5]
Evermann, Barton Warren, Golden Gate Park, San Francisco, Cal.[5]
Goss, William Freeman M., 61 Broadway, N.Y., Fellow.....1893
Greene, Charles Wilson, 814 Virginia Ave., Columbia, Mo.[5]
Hargitt, Charles W., 909 Walnut St., Syracuse, N.Y.[5]
Hay, Oliver Perry, U.S. National Museum, Washington, D.C.....1893
Jordan, David Starr, Stanford, Cal.....1893
Kingsley, John S., Urbana, Ill.[5]
Knipp, Charles T., 915 W. Nevada St., Urbana, Ill.....1894
MacDougal, Daniel Trembly, Tucson, Ariz.[5]
McMullen, Lynn Banks, 641 Euclid Ave., Valley City, N.D.....1900
Marsters, Vernon F., Kansas City, Mo., care of C. N. Gould, Fellow..1893
Miller, John Anthony, Swarthmore, Pa., Fellow.....1904
Moore, George T., Missouri Botanical Garden, St. Louis, Mo.....1909
Noyes, William Albert, Urbana, Ill., Fellow.....1893
Ransom, James H., Detroit, Mich., Fellow.....1902
Reagan, Albert B., Cornfields, Ganado, Ariz.....1902

[4] Date of membership or fellowship.
[5] Elected previous to 1891.

Springer, Alfred, 312 E. Second St., Cincinnati, Ohio
Swain, Joseph, Swarthmore, Pa., Fellow.....1898
Von Kleinsmid, R. B., Tucson, Ariz.....1920
Waldo, Clarence A., Fellow (address not known).....1893
Wiley, Harvey W., Woodward Building, Washington, D.C.....1895
Zeleny, Chas., 1003 W. Illinois St., Urbana, Ill.....1904

ACTIVE MEMBERS.

Acre, Harlan Q., Gordon, Nebr.....1918[6]
Adams, James Edward, 419 W. Wood St., West Lafayette.....1921
Adams, William B., 431 S. College Ave., Bloomington.....1919
Addington, Archie, 801 Atwater Ave., Bloomington.....1921
Allee, W. N., 221 E. Fourth St., Bloomington.....1922
Allen, William Ray, University of Kentucky, Lexington, Ky.....1912
Allison, Luna Evelyn, 435 Wood St., West Lafayette.....1908
Anderegg, Frederick O., 322 Waldron St., West Lafayette.....1918
Anderson, Flora Charlotte, 327 S. Henderson St., Bloomington.....1914
Armington, John H., U.S. Weather Bureau, Indianapolis.....1921
Atkinson, F. C., 2534 Broadway, Indianapolis.....1914
Auble, Robert N., 409 N. Wolcott St., Indianapolis.....1922
Baker, Lora M., 804 S. Grant St., Bloomington.....1920
Baker, Wm. F., Box 586, Carmel.....1914
Balcom, Stephen F., 3634 Birchwood Ave., Indianapolis.....1920
Baldwin, Ira L., 849 N. Salisbury St., West Lafayette.....1919
Barnett, Horace L., Indiana University, Bloomington.....1922
Barnhill, Dr. T. F., Indiana Univ. School of Medicine, Indianapolis.1916
Barr, Harry L., Buckley, Ill. 1911
Barrett, Edward, State Geologist, Indianapolis.....1911
Beals, Colonzo, 103 Russell St., Hammond.....1915
Becktel, Albert R., 209 W. College St., Crawfordsville.....1920
Beecher, Alva, 1010 E. Pike St., Crawfordsville.....1922
Beeson, K. E., 427 State St., West Lafayette.....1922
Begeman, Hilda, 24 Linden St., Wellesley, Mass.....1919
Bell, Alva Marie, 511 Smith Ave., Bloomington.....1922
Berg, George F., Jr., 3518 Balsam Ave., Indianapolis.....1922
Berteling, Dr. J. B., 228 Colfax Ave., South Bend.....1914
Black, Homer F., 2721 S. Michigan Ave., Chicago, Ill.....1916
Bockstahler, Lester, 101 Haven House, Evanston, Ill.....1920
Bodine, Mrs. Emma, 4 Mills Place, Crawfordsville.....1921
Bolen, Homer R., 314 S. Grant St., Bloomington.....1922
Bond, Dr. Charles S., 112 N. Tenth St., Richmond.....1900
Bond, Dr. George S., 112 N. Tenth St., Richmond.....1916
Boots, Edwin B., 125 N. 6th St., West Terre Haute.....1922
Bourke, Adolphus A., 2304 Liberty Ave., Terre Haute.....1909
Brewer, P. H., 145 E. Oak St., West Lafayette.....1921
Brock, James E., Sweetser 1922

[6] Date of membership in the Academy.

Brosey, Charles L., 766 W. Drive, Woodruff Place, Indianapolis....1922
Brossmann, Charles, 1503 Merchants Bank Bldg., Indianapolis.....1909
Bruce, Edwin M., 2108 N. Tenth St., Terre Haute.....1918
Burton, Everett T., 3100 Broadway, New York, N.Y.....1920
Bushnell, T. M., Agr. Exp. Sta., West Lafayette.....1922
Bybee, Halbert P., University Station, Austin, Texas.....1912
Byers, Cecil W., Box 332, University Station, Grand Forks, N.D....1919
Cain, Stanley A., 30 N. Holmes St., Indianapolis.....1921
Campbell, Elmer G., 220 Sylvia St., West Lafayette.....1919
Campbell, Marion S., 29 N. Hawthorne Lane, Indianapolis.....1921
Canis, Edward N., Route A-2, Box 372-A, Indianapolis.....1909
Caparo, Jose Angel, Notre Dame University, South Bend.....1914
Carter, Edgar B., 4555 Central Ave., Indianapolis.....1918
Cassady, Emil V., 1841 C.D., Woodruff Place, Indianapolis.....1920
Cavins, Alexander, 1232 N. Alabama St., Indianapolis.....1920
Chansler, Elias J., Bicknell.....1895
Chapman, Edgar K., 506 S. Grant St., Crawfordsville.....1911
Chitty, Ethel, Indiana State Normal, Muncie.....1922
Christy, O. B., Indiana State Normal, Muncie.....1919
Clark, Jediah H., 126 E. Fourth St., Connersville.....1909
Clay, Mrs. Celia, 320 N. State St., Kendallville.....1922
Cleveland, Clarence R., Purdue Agricultural Exp. Sta., Lafayette..1921
Cloves, G. H. A., Eli Lilly & Co., Indianapolis.....1920
Coggeshall, Lowell, 339 S. Walnut St., Bloomington.....1921
Conner, S. D., 204 S. Ninth St., Lafayette.....1912
Cook, Rolla V., 600 E. Second St., Bloomington.....1922
Coryell, Noble H., Columbia University, New York, N. Y.....1914
Cottman, Evans W., Lanier Place, Madison.....1921
Cox, C. F., 528 N. Oxford St., Indianapolis.....1922
Crozier, Alice M., 312 Kenmore Rd., Indianapolis.....1921
Curtis, Lila C., 406 N. Fess Ave., Bloomington.....1920
Danglade, Ernest, Vevay 1920
Davis, Charles, 217 Sylvia St., West Lafayette.....1922
Davis, Hugh L., 423 Vine St., West Lafayette.....1921
Davis, John J., Purdue University, Lafayette.....1920
Davis, Ward B., Botany Bldg., University of Chicago, Chicago, Ill...1921
Dean, Miss Grace, French Lick.....1922
Dean, John C., University Club, Indianapolis.....1914
deForest, Howard, Indianapolis Normal School, Indianapolis.....1921
Demaree, Delzie, Benham.....1920
Deppe, C. A., Franklin.....1911
Derby, Ira Harris, 5460 University Ave., Indianapolis.....1920
Deuker, Henry W., Jr., Y.M.C.A., Indianapolis.....1921
Dietz, Chas. D., 3121 Fairfield Ave., Ft. Wayne.....
Dietz, Emil, 334 Congress Ave., Indianapolis.....1921
Diggs, John C., 54 Kealing Ave., Indianapolis.....1920
Dilts, Charles D., 3121 Fairfield Ave., Ft. Wayne.....1920
Doan, Martha, Earlham 1896
Doan, Richard L., 802 E. Third St., Bloomington.....1922

Dolan, Joseph P., Syracuse....1895
Domroese, Fred C., 815 W. Main St., Crawfordsville....1920
Donahue, Joseph N., Columbia University, Portland, Ore....1920
Douglass, Benjamin W., Trevlac....1916
Downhour, Elizabeth, 1817 Broadway, Indianapolis....1915
Dugan, Elizabeth, 717 N. Tremont St., Indianapolis....1922
Dunham, David H., 429 Main St., West Lafayette....1920
Earp, Samuel E., 634 Occidental Bldg., Indianapolis....1909
East, Mrs. Pearl W., Gilman, Iowa....1920
Eaton, Dunwald L., Indiana Central College, Indianapolis....1922
Edmonson, Clarence E., 822 Atwater Ave., Bloomington....1912
Eisenhard, Geo. B., Culver Military Academy, Culver....1921
Eisenhard, Mrs. Geo. B., Culver....1921
Eldred, Frank P., 2823 N. Delaware St., Indianapolis....1918
Elkin, Sarah K., 612 Harvey Ave., West Lafayette....1921
Emerson, Dr. Charles P., 602 Hume-Mansur Bldg., Indianapolis....1915
Estabrook, Arthur H., Board of State Charities, Indianapolis....1916
Etter, Austin, 931 Cass Ave., S. E., Grand Rapids, Mich....1920
Evans, Samuel G., 1452 Upper Second St., Evansville....1891
Feldman, Horace W., 138 Chauncey Ave., West Lafayette....1920
Ferguson, Luther S., State Geologist's Office, Indianapolis....1920
Foresman, George K., 110 S. Ninth St., Lafayette....1914
Franklin, Fred F., Washington....1921
Friesner, Ray C., Butler College, Indianapolis....1919
Froning, Henry B., 415 Pokagon St., South Bend....1920
Fugate, Mary, 2525 Park Ave., Indianapolis....1920
Fuller, F. D., 3021 College Ave., Bryan, Texas....1910
Funk, Dr. Austin, 404 Spring St., Jeffersonville....1895
Galloway, Jesse J., Geology Dept., Columbia Uni., New York, N. Y..1910
Gantz, Richard A., State Normal School, Muncie....1920
Gardner, Max William, Purdue Agr. Exp. Station, Lafayette....1919
Garver, Frederick R., 510 E. 5th St., Bloomington....1922
Gatch, Willis D., 605 Hume-Mansur Bldg., Indianapolis....1915
Gates, Florence A., 3435 Detroit Ave., Toledo, Ohio....1909
Gayler, Dona G., 200 N. Sixth St., Terre Haute....1920
Gidley, William F., 276 Littleton St., West Lafayette....1914
Gillum, Robert G., Indiana State Normal, Terre Haute....1913
Gingery, Walter G., Shortridge High School, Indianapolis....1918
Goldsmith, William M., Southwestern College, Winfield, Kansas....1914
Graves, Benjamin H., 604 E. Market St., Crawfordsville....1920
Greene, Frank C., 1434 Cincinnati Ave., Tulsa, Okla....1908
Gregory, Charles T., 1022 First St., W. Lafayette....1922
Guernsey, E. Y., 120½ W. 46th St., Los Angeles, Calif....1921
Guthrie, W. A., 10 E. Market St., Indianapolis....1920
Hadley, Joel W., 1127 Fairfield Ave., Indianapolis....1919
Hagey, G. L., 219 Wiggins St., West Lafayette....1920
Hanna, U. S., Atwater Ave., Bloomington....1914
Hansen, Albert A., Purdue Agri. Exp. Station, Lafayette....1921
Hansford, Hazel I., Southeastern Hosp. for Insane, North Madison..1916

Happ, William, South Bend....1914
Harding, Charles F., 503 University St., West Lafayette....1918
Hardy, Eugene H., 1230 S. Keystone Ave., Indianapolis....1920
Harmon, Paul M., 311 E. South Ave., Bloomington....1915
Hassenzahl, Elizabeth, 424 Vine St., West Lafayette....1921
Hedebol, Frederick C. N., 809 W. Grand Blvd., Springfield, Ill....1920
Heimburger, Harry V., Hamline Ave., St. Paul, Minn....1912
Heimlich, Louis F., 495 Littleton St., West Lafayette....1914
Hendricks, Victor K., 131 N. Eighth St., Terre Haute....1900
Hess, Walter N., S. College Ave., Greencastle....1917
Hills, Donald H., 2127 Talbott Ave., Indianapolis....1922
Hinman, Jack J., University of Iowa, Iowa City, Iowa....1912
Hoffer, Geo. N., 434 Littleton St., West Lafayette....1909
Hoffman, A. C., 920 E. Drive, Woodruff Place, Indianapolis....1922
Hoffman, G. L., Western Pennsylvania Hospital, Pittsburg, Pa....1911
Hole, Allen D., 615 National Road West, Richmond....1901
Howick, Howard, Indiana State Normal, Muncie....1921
Howlett, Berton A., 503 Elm St., Valparaiso....1919
Huber, Leonard L., Hanover....1915
Hufferd, Ralph, Greencastle....1920
Hull, Julia, St. Anne, Ill....1919
Hutchinson, Emory, Norman Station....1915
Hutton, Joseph G., State College, Brookings, S. D....1911
Hyslop, George H., 143 Twenty-second St., Long Island, N. Y....1914
Irving, Thomas P., Notre Dame University, South Bend....1914
Jackson, James W., Central High School, Chattanooga, Tenn....1918
James, Charles M., 443 Wood St., West Lafayette....1921
James, Evalyn G., 144 Butler Ave., Indianapolis....1919
Jensen, Howard E., 360 Downey Ave., Indianapolis....1921
Kaczmarek, Regidius M., Box 54, Notre Dame Uni., South Bend....1914
Kantor, Jacob R., 645 N. Walnut St., Bloomington....1920
Katterjohn, Mable C., Lynnville....1920
Kendrick, James B., Purdue Agri. Exp. Station, Lafayette....1921
Kennedy, Clarence H., Ohio State Univ., Columbus, Ohio....1922
Kiester, Jackson A., 300 S. Green St., Crawfordsville....1922
Kinsey, Alfred C., S. Park Ave., Bloomington....1920
Klipinger, Walter C., 2234 Park Ave., Indianapolis....1922
Knecht, Christian, 207 N. Dunn St., Bloomington....1922
Knotts, Armanis F., Anglis, Fla....1917
Koch, E. W., 24 High St., U. S. Medical Dept., Buffalo, N. Y....1914
Kohl, Edwin J., 218 Fowler Ave., West Lafayette....1917
Lanham, Miss Bess, 610 E. Wabash Ave., Crawfordsville....1922
Larrimer, Walter H., Box 95, West Lafayette....1921
Lieber, Richard, State House, Indianapolis....1919
Liston, Jesse G., R.F.D. 2, Lewis....1916
Ludwig, C. A., Clemson College, S.C....1911
Ludy, Llewellyn V., 600 Russell St., West Lafayette....1908
Luten, Daniel B., 1056 Lemcke Annex, Indianapolis....1918
Lyon, Marcus Ward, Jr., 214 LaPorte Ave., South Bend....1922
Mains, E. B., 212 S. Grant St., W. Lafayette....1916

Maloney, Wm., Notre Dame University, South Bend.....
Malott, Burton J., Technical High School, Indianapolis.....1916
Malott, Clyde A., 521 E. 2nd St., Bloomington.....1914
Malott, Ruth Boyd, 629 Carlisle Place, Indianapolis.....1914
Mannfeld, George N., 1235 Central Ave., Indianapolis.....1922
Martin, Elsie S., 134 N. Drexel St., Indianapolis.....1922
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis.....1922
Mason, Thomas E., 130 Andrew Place, West Lafayette.....1905
McAvoy, Miss Blanche, Muncie.....1921
McCarty, Morris, High School, Montmorenci.....1917
McDonald, Clinton C., 415 S. Dunn St., Bloomington.....1922
McDonald, Doloris, 526 E. 5th St., Bloomington.....1921
McEachron, Karl B., 335 Lutz Ave., West Lafayette.....1921
McGavran, Edward, Downey Ave., Indianapolis.....1921
Mellon, M. G., 403 Russell St., West Lafayette.....1921
Michael, Lyle Jordan, Indiana Central College, Indianapolis.....1922
Miller, Fred A., Eli Lilly Co., Greenfield.....1908
Miller, John W., 115 E. Columbia St., West Lafayette.....1919
Montgomery, Basil E., Poseyville.....1922
Montgomery, H. T., 208 Dean Building, South Bend.....1898
Moore, John Irwin, Owensville.....1922
Moore, Kenneth W., 125 Downey Ave., Indianapolis.....1921
Moorhead, John G., 124 DeHart St., West Lafayette.....1922
Morgan, Frank W., Science Hall, Valparaiso.....1920
Morgan, Will, University Heights, Indianapolis.....1920
Morrison, Harold, Bureau of Entomology, Washington, D.C.....1910
Morrison, Louis A., care Edward Morrison, Mich. Agric. Coll., East Lansing, Mich. 1917
Muldoon, Hugh C., 502 Main St., Valparaiso.....1920
Mullendore, Miss Naomi, Franklin 1922
Munro, George W., 202 Waldron St., West Lafayette.....1917
Myers, B. D., 321 N. Washington St., Bloomington.....1911
Nelson, Ralph E., 232 Littleton St., West Lafayette.....1914
Nicholson, Thomas E., 519 N. Fess Ave., Bloomington.....1918
Niles, Edward H., 4450 Guilford Ave., Indianapolis.....1920
Noble, Willis Bernard, Box 95, West Lafayette.....1922
Noyes, Harry A., State Dept. of Agriculture, Lansing, Mich.....1916
Oberholser, Harry C., U. S. National Museum, Washington, D.C.....1914
O'Neal, Claude E., Forrest Ave., Delaware, Ohio.....1912
Orahood, Harold, Union Mills.....1914
Orton, Clayton R., State College, Pa.....1910
Osbun, Clifford Leroy, 201 Russell St., West Lafayette.....1922
Owen, D. A., 200 S. State St., Franklin.....1885
Painter, Henry R., Box 95, West Lafayette.....1921
Payne, Mary G., 303 S. Downey Ave., Indianapolis.....1922
Pearson, George B., Box 95, West Lafayette.....1921
Pearson, Nathan E., Indiana University, Bloomington.....1922
Peffer, Harry C., 1022 Seventh St., West Lafayette.....1914
Petry, Edward J., 625 Twelfth Ave., Brookings, S. D.....1911
Pickett, Fermen L., Station 36, Pullman College, Washington.....1909

Pinkerton, Earl, Box 447, Walters, Okla.....1916
Pitkin, Edward M., 519 N. College St., Bloomington.....1922
Pollard, Cash B., 419 W. Wood St., West Lafayette.....1921
Prentice, Burr N., 400 Russell St., West Lafayette.....1915
Price, Walter A., 123 Sheetz St., West Lafayette.....1919
Proulx, Edward G., 111 Waldron St., West Lafayette.....1918
Raab, Albert L., 1351 Consolidated Bldg., Indianapolis.....1921
Rawles, William P., 924 E. Third St., Bloomington.....1920
Records, Ralph L., Edinburg.....1920
Reeves, John R., 414 E. Third St., Bloomington.....1920
Reinhard, Herbert F., Room 152, State House, Indianapolis.....1921
Richards, Dr. and Mrs. Aute, University of Oklahoma, Norman, Okla. 1916
Ridgway, Robert, 1030 S. Morgan St., Olney, Ill.....1920
Rifenburgh, S. A., Valparaiso.....1916
Riley, Katherine, 56 Whittier Place, Indianapolis.....1916
Roark, Louis, Box 1266, Okmulgee, Okla.....1917
Roberts, Chester R., 901 E. Jefferson St., Franklin.....1919
Roberts, Harry John, Route A., Lafayette.....1922
Robertson, Pay S., 702 Evergreen St., West Lafayette.....1922
Scnour, Frank C., 323 N. Grant St., Bloomington.....1922
Sheak, Wm. H., Ijamsville.....1916
Sherman, George W., 8 Murdock Flats, West Lafayette.....1918
Shonle, Horace A., Eli Lilly & Co., Indianapolis.....1919
Showalter, Ralph W., Eli Lilly & Co., Indianapolis.....1915
Silvey, Oscar W., College Station, Texas.....1909
Smith, Charles Piper, 354 S. Tenth St., San Jose, Calif 1903
Smith, Ernest R., Greencastle.....1921
Smith, John C., Route 6, Franklin.....1919
Smith, Lee T., R.F.D. 7, Bloomington.....1922
Smith, Paul R., University of Pennsylvania, Philadelphia, Pa.....1920
Snodgrass, Robert E., U. S., Agricultural Station, Wallingford, Conn. 1917
Spitzer, George, 1000 Seventh St., West Lafayette.....1909
Spong, Philip, 3873 E. Washington St., Indianapolis.....1916
Stacy, Allan R., 1555 Ashland Ave., Indianapolis.....1921
Stirrett, George M., 521 State St., West Lafayette.....1922
Stone, Ralph B., 307 Russell St., West Lafayette.....1914
Strickler, Alvin, Evansville College, Evansville.....1922
Sulzer, Elmer G., Madison.....1918
Suter, E. M., 1437 Broadway, Ft. Wayne.....1920
Tasker, Roy C., 612 Anderson St., Greencastle.....1922
Tatlock, Myron W., Shortridge High School, Indianapolis.....1918
Taylor, George O., 502 S. Sluss Ave., Bloomington.....1922
Telfer, Margaret, 403 W. 5th St., Bloomington.....1921
Terry, Dr. Oliver P., 215 Sheetz St., West Lafayette.....1914
Test, Louis A., 511 Russell St., West Lafayette.....1918
Tetrault, Philip A., 607 University St., West Lafayette.....1914
Tevis, Emma L., 122 W. Eighteenth St., Indianapolis.....1916
Thompson, Clem O., Hanover.....1911

Thompson, James T., 334 Lafayette Ave., Lebanon.....1920
Thornburn, A. D., 42 E. 37th St., Indianapolis.....1909
Thrasher, Mrs. John R., Apt. 1, 3805 N. Delaware St., Indianapolis.1921
Treat, Frank M., Atwater Ave., Bloomington.....1920
Troop, James, 123 Sheetz St., West Lafayette.....1914
Tucker, William Motier, 505 Ballantine Road, Bloomington.....1910
Turley, Harold E., Am. Baking Inst., Chicago, Ill.....1921
Turner, B. B., 1017 Park Ave., Indianapolis.....1916
Turner, William P., 222 Lutz Ave., West Lafayette.....1908
Twitty, Victor, 4922 Central Ave., Indianapolis.....1921
Van Nuys, W. C., Newcastle.....1914
Visher, Stephen S., 817 E. 2nd St., Bloomington.....1919
Voorhees, Herbert S., 804 Wildwood Ave., Ft. Wayne.....1896
Wallace, Frank N., Dept. of Entomology, State House, Indianapolis.1920
Ward, Mary Mallory, 405 E. William St., Kendallville.....1922
Weems, Mason L., 102 Greenfield Ave., Valparaiso.....1919
Wenninger, Rev. Francis J., Notre Dame University, South Bend..1920
Wiancko, Alfred T., 230 S. Ninth St., Lafayette.....1909
Wildman, Ernest A., Earlham.....1918
Wiley, Ralph B., 227 Russell St., West Lafayette.....1914
Wilhite, Miss Ida B., Butler College, Indianapolis.....1921
Wilkinson, Paul D., 300 S. 4th St., Terre Haute.....1921
Williams, A. A., Valparaiso.....1916
Williamson, Jesse H., Bluffton.....1921
Wilson, Arthur J., 901 W. Wabash St., Crawfordsville.....1920
Wilson, E. R., 2830 E. Vermont St., Indianapolis.....1922
Wilson, Mrs. Etta, 9077 Clarendon Ave., Detroit, Mich.....1915
Wilson, Geo. B., 427 State St., West Lafayette.....1921
Wilson, Ira T., 521 Kirkwood Ave., Bloomington.....1919
Winkenhofer, Walter, Huntingburg.....1920
Witmer, Samuel W., 1405 Ninth St., Goshen.....1921
Wolfe, Harold E., 314 N. Washington St., Bloomington.....1920
Wood, Harry W., 5923 Winthrop Ave., Chicago, Ill.....1912
Woodruff, Albert E., University of Chicago, Chicago, Ill.....1921
Young, Gilbert A., 739 Owen St., Lafayette.....1908
Young, Herman, 602 N. College St., Bloomington.....1922
Young, Paul A., 605 W. University Ave., Urbana, Ill.....1920
Yuncker, Truman G., 203 Wood St., Greencastle.....1919
Zebrowski, George, 244 Harrison St., West Lafayette.....1920
Zehring, William A., 303 Russell St., West Lafayette.....1907
Zerfas, Leon G., Indiana University Medical School, Indianapolis...1921
Zierer, Clifford M., Indiana University, Bloomington.....1922

SUMMARY OF MEMBERSHIP.

Fellows	58
Members, active	325
Members and Fellows, non-resident	31
Total	414

PROCEEDINGS

OF THE

THIRTY-NINTH ANNUAL MEETING

OF THE

INDIANA ACADEMY OF SCIENCE

1923

VOLUME 33

PROCEEDINGS

OF THE

INDIANA ACADEMY OF SCIENCE

THIRTY-NINTH ANNUAL MEETING

1923

VOLUME 33

J. J. DAVIS, EDITOR

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING
1924

TABLE OF CONTENTS

PAGE

Aims and Purposes of the Indiana Academy of Science 5
Officers and Committees for 1923 7
Past Officers of the Academy 9
Minutes of the Spring Meeting, 1923 11
Early History of the Indiana Academy of Science: Amos W. Butler .. 14
Brookville and its Contribution to the Intellectual Life of the State: John C. Shirk 19
Winter Meeting 23
Program 23
Minutes of Business Session 27
Minutes of General Session 31

Papers—General—
President's Address—Bacteriology and its Practical Significance: Charles A. Behrens 35
A Plea Against Over-Standardization in Scientific Education: E. G. Mahin 47
Geographic Variations in Indiana in Typhoid, Tuberculosis, Cancer and in Total Deaths: Stephen Sargent Visher 55
Papers of Geology, Geography, and Archeology—
A Change of Drainage of Raccoon Creek, Parke County, Indiana: Glenn G. Bartle 63
The Development of Soil Survey: T. M. Bushnell 69
A Case of Stream Piracy near Greencastle, Indiana: Ernest Rice Smith 73

Papers on Chemistry and Physics—
The Silent Electric Discharge and its Effect on Gases: R. H. George and K. A. Oplinger 77
The Electrometric Titration of Boric Acid in the Presence of Polyphenols and Organic Acids: M. G. Mellon and V. N. Morris 85
†The Peculiar Properties of Water in Light of its Molecular Structure: F. O. Anderegg 93
Familiarizing Chemistry Students with the Gram-Molecular Volume of Gases: W. M. Blanchard 103
A Study of Locomotive Whistles: Arthur L. Foley 105
The Power Required to Drive Spoke and Disk Wheels and Pulleys: Arthur L. Foley and B. Eisenhour 115
Why the Logarithm in Logarithmic Decrement?: R. R. Ramsey 121

Papers on Botany, Zoology and Entomology—
†List of Indiana Plants, chiefly from Putnam County, collected 1919–1915 by Earl J. Grimes: Eileen W. Erlanson 123
†Indiana Plant Diseases, 1921: Max W. Gardner 163
Indiana Plant Diseases, 1922: Max W. Gardner 202

†Presented at the 1922 Meeting.

PAGE

Does Allium vineale L. Produce Seeds in Indiana?: Albert A. Hansen 213
Recent Indiana Weeds, 1923: Albert A. Hansen 214
†A Weed Survey of Indiana: Albert A. Hansen 216
Plants New or Rare in Indiana, XII.: Chas. C. Deam 221
Notes on Grasses: Paul Weatherwax 223
Plants of White County, VI.: Louis F. Heimlich 225
Indiana Fungi, VII.: J. M. Van Hook 233
Culture Methods in the Production of Polyembryony in Certain Ferns (Polypodiacea): David M. Mottier 239
Notes on Greenhouse Culture Methods in Rust Investigations: E. B. Mains 241
The Reclamation of Soil by Vegetation: F. M. Andrews 259
Midsummer Growth: F. M. Andrews 264
Studies on Pollen, IV.: F. M. Andrews 265
Protoplasmic Streaming: F. M. Andrews 266
Nitrate Studies on Purdue Rotation Field No. 6: I. L. Baldwin, W. J. Nichter, and R. O. Lindsey 269
Some Soil and Water Reactions in the Dunes Region of Porter County: Marcus Ward Lyon, Jr 281
New Records of Indiana Mammals: Marcus Ward Lyon, Jr 284
†Relation of Insects to Human Life and to the Sciences: J. J. Davis 287
†Notes on the Termites of Indiana, II.: Harry F. Dietz 299
Notes on the Function of the Forceps of Earwigs: W. P. Morgan 303
The Relation of Size to Age in Some Common Freshwater Fishes: Homer R. Bolen 307
The Diurnal Oxygen Pulse in Eagle (Winona) Lake: Will Scott 311
A Study of the Productivity and Breeding Habits of the Bluegill, *Lepomis pallidus* (Mitch.): Lowell T. Coggeshall 315
Members 321

†Presented at the 1922 Meeting

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PURPOSES AND AIMS OF THE INDIANA ACADEMY OF SCIENCE.

The Indiana State Academy of Science was founded December 29, 1885, by a group of zealous workers in the field of science. During the 38 years of active development it has published 32 volumes of scientific papers of high character and immense value, including studies on the fauna and flora of the state, conservation of forests, topographic, meteorological, and many other studies which have reacted favorably on the health and prosperity of the people of the state. The Academy has benefited and encouraged several thousand men and women and has helped to train some of the foremost scientists of the past few decades; it is now the most important and representative body of scientists in Indiana and as such has acted as a clearing house for scientific information; and by the acquaintances and contacts there has developed a feeling which has indirectly increased the efficiency and usefulness of all who are fortunate in regularly attending the annual meetings.

The Academy has been of incalculable value to the State of Indiana in raising the level of intellectual life, making familiar the idea and worth of research, in bringing the greatness of Indiana to the eyes of the world, and, in a word, contributing in a large measure to our economic prosperity.

"The object of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science", according to the Constitution, in other words, to stimulate and encourage scientific work so as to make it an important adjunct to the educational system of the state. The Academy fosters scientific research and its members are constantly extending the boundaries of knowledge and making scientific truths serviceable to the citizens of the state. In the realms of Zoölogy, Entomology, Botany, Bacteriology, Mathematics, Physics, Chemistry, Geology, Medicine, Engineering and Agriculture and in the practical conservation of the national resources of the state, our Academy is rendering a valuable service. The Academy acts as an important factor in education, in promoting interest in and appreciation of science among the citizens of the state, especially among the students of our high schools, colleges and universities; enabling teachers of science in our common schools to maintain their contact and to stimulate them to continue research for which many are well trained that they may materially contribute to the scientific data by devoting their spare time to some phase of science in their own locality and also that they may better inspire their students; and finally by offering to students and amateurs incentives and opportunities to present for constructive and friendly criticism the results of their efforts.

Co-operation is the basis for many of the Academy's activities. The Constitution specifically states that it shall be the duty of the Academy to assist the various state agencies in an advisory capacity

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

JUN 6 1924

in the direction and execution of any investigations within its province without pecuniary gain to the Academy. Similarly, it is a function of the Academy to guide and counsel individuals and companies engaged in economic activities in the solution of problems involving scientific research. The regular annual meetings stimulate better acquaintances, establish friendships, offer opportunities for the mutual discussion of various interests and problems, and become not only a personal aid but give the advantage that organization and co-operation have over isolated effort.

The Academy is a productive agency. It brings together at its annual meetings the results of scientific activity for the preceding year. These results are published in the annual Proceedings and made available to the people of the state, nation, and world, and thus the name of Indiana and its scientific achievements are carried to all the educated peoples.

The Academy becomes a utilitarian agency by furnishing information of practical value to the citizens of Indiana. The scientific facts concerning the agricultural, mining and manufacturing industries and the facts concerning the natural resources of the state which they publish in the annual Proceedings of the Academy materially aid in the development of all our industries.

As has been noted, the State Academy fosters scientific research and affords, through the Proceedings, a vehicle for the publication of the results of such investigations. It is a big factor in education. It is the representative scientific organization of the state and as such should include in its membership all Indianians who are directly or indirectly interested in science and because of its importance as a contributing factor in the education of the citizens and development of the industries of the state, it should continue to have the moral and financial support of the state.

OFFICERS AND COMMITTEES FOR 1923.

President, CHARLES A. BEHRENS, Purdue University, Lafayette.
Vice-President, F. PAYNE, Indiana University, Bloomington.
Secretary, WALTER N. HESS, DePauw University, Greencastle.
Assistant Secretary, FLORA ANDERSON, Indiana University, Bloomington.
Press Secretary, HARRY F. DIETZ, State Conservation Commission, Indianapolis.
Treasurer, WILLIAM M. BLANCHARD, DePauw University, Greencastle.
Editor, 1922 Proceedings, J. J. DAVIS, Purdue University, Lafayette.

Executive Committee:

(Officers and Past-President)

ANDERSON, FLORA
ANDREWS, F. M.
ARTHUR, J. C.
BEHRENS, C. A.
BIGNEY, A. J.
BLANCHARD, W. M.
BLATCHLEY, W. S.
BRUNER, H. L.
BURRAGE, SEVERANCE
BUTLER, AMOS W.
COGSHALL, W. A.
COULTER, JOHN M.
COULTER, STANLEY
CULBERTSON, GLENN
DAVIS, J. J.
DIETZ, H. F.
DRYER, CHAS. R.
EIGENMANN, C. H.
ENDERS, HOWARD E.
EVANS, P. N.
FOLEY, A. L.
HAY, O. P.
HESS, W. N.
HESSLER, ROBERT
JORDAN, D. S.
MOENKHAUS, W. J.
MOTTIER, DAVID M.
NAYLOR, JOSEPH P.
NOYES, W. A.
PAYNE, F.
WALDO, C. A.
WILEY, W. H.
WILLIAMSON, E. B.
WRIGHT, JOHN S.

Curators:

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ENTOMOLOGY ..... W. S. BLATCHLEY
HERPETOLOGY, MAMMALOGY, ORNITHOLOGY ..... A. W. BUTLER
ICHTHYOLOGY ..... C. H. EIGENMANN

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JOHN S. WRIGHT, Indianapolis.
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AMOS W. BUTLER, Chairman, 52 Downey Ave., Irvington, Indianapolis.
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HOWARD E. ENDERS, Chairman, 249 Littleton St., West Lafayette.
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Distribution of Proceedings.

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Program.

WM. M. BLANCHARD, Chairman, 1008 S. College Ave., Greencastle.
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Publication of Proceedings.

J. J. DAVIS, Chairman, Purdue University, Lafayette.
RALPH H. CARR, Lafayette.
RAY C. FRIESNER, Indianapolis.

Relation of Academy to the State.

ROBERT W. MCBRIDE, Chairman, 1239 State Life Bldg., Indianapolis.
GLENN CULBERTSON, Hanover.
JOHN S. WRIGHT, Indianapolis.
FRANK N. WALLACE, Indianapolis.
DAVID A. ROTHROCK, Bloomington.

Research.

ARTHUR L. FOLEY, Chairman, Bloomington.
JOHN S. WRIGHT, Indianapolis.
E. G. MAHIN, Lafayette.
E. B. WILLIAMSON, Bluffton.
J. P. NAYLOR, Greencastle.
D. M. MOTTIER, Bloomington.

State Library.

AMOS W. BUTLER, Chairman, 52 Downey Ave., Irvington, Indianapolis.
W. S. BLATCHLEY, Indianapolis.
ARTHUR L. FOLEY, Bloomington.

PAST OFFICERS OF THE INDIANA ACADEMY OF SCIENCE

YEARS	PRESIDENT	SECRETARY	ASST. SECRETARY	PRESS SECRETARY	TREASURER
1885–1886	David S. Jordan	Amos W. Butler			O. P. Jenkins.
1886–1887	John M. Coulter	Amos W. Butler			O. P. Jenkins.
1887–1888	*J. P. D. John	Amos W. Butler			O. P. Jenkins.
1888–1889	*John C. Branner	Amos W. Butler			O. P. Jenkins.
1889–1890	T. C. Mendenhall	Amos W. Butler			O. P. Jenkins.
1890–1891	O. P. Hay	Amos W. Butler			O. P. Jenkins.
1891–1892	*J. L. Campbell	Amos W. Butler			C. A. Waldo.
1892–1893	J. C. Arthur	Amos W. Butler	{Stanley Coulter} {W. W. Norman}		C. A. Waldo.
1893–1894	W. A. Noyes	C. A. Waldo	W. W. Norman.		W. P. Shannon.
1894–1895	A. W. Butler	John S. Wright	A. J. Bigney		W. P. Shannon.
1895–1896	Stanley Coulter	John S. Wright	A. J. Bigney		W. P. Shannon.
1896–1897	*Thomas Gray	John S. Wright	A. J. Bigney		W. P. Shannon.
1897–1898	C. A. Waldo	John S. Wright	A. J. Bigney	Geo. W. Benton	J. T. Scovell.
1898–1899	C. H. Eigenmann	John S. Wright	E. A. Schultz	Geo. W. Benton	J. T. Scovell.
1899–1900	*D. W. Dennis	John S. Wright	E. A. Schultz	Geo. W. Benton	J. T. Scovell.
1900–1901	*M. B. Thomas	John S. Wright	E. A. Schultz	Geo. W. Benton	J. T. Scovell.
1901–1902	Harvey W. Wiley	John S. Wright	DonaldsonBodine	Geo. W. Benton.	J. T. Scovell.
1902–1903	W. S. Blatchley	John S. Wright	DonaldsonBodine	G. A. Abbott	W. A. McBeth.
1903–1904	C. L. Mees	John S. Wright	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1904–1905	John S. Wright	Lynn B. McMullen	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1905–1906	Robert Hessler	Lynn B. McMullen	J. H. Ransom	Charles R. Clark	W. A. McBeth.
1906–1907	D. M. Mottier	Lynn B. McMullen	J. H. Ransom	G. A. Abbott	W. A. McBeth.
1907–1908	Glenn Culbertson.	J. H. Ransom	A. J. Bigney	G. A. Abbott	W. A. McBeth.
1908–1909	A. L. Foley	J. H. Ransom	A. J. Bigney	G. A. Abbott	W. A. McBeth.
1909–1910	P. N. Evans	Geo. W. Benton	A. J. Bigney	J. W. Woodhams	W. J. Moenkhaus.
1910–1911	C. R. Dryer	A. J. Bigney	E. B. Williamson	Milo H. Stuart	W. J. Moenkhaus.
1911–1912	J. P. Naylor	A. J Bigney	E. B. Williamson	Milo H. Stuart	W. J. Moenkhaus.
1912–1913	*Donaldson Bodine	A. J. Bigney	C. M. Smith	F. B. Wade	W. J. Moenkhaus.
1913–1914	Severance Burrage	A. J. Bigney	H. E. Enders	F. B. Wade	W. A. Cogshall.
1914–1915	W. A. Cogshall	A. J. Bigney	H. E. Enders	F. B. Wade	Wm. M. Blanchard.
1915–1916	A. J. Bigney	Howard E. Enders	E. B. Williamson	F. B. Wade	Wm. M. Blanchard.
1916–1917	W. J. Moenkhaus	Howard E. Enders	P. A. Tetrault	F. B. Wade	Wm. M. Blanchard.
1917–1918	E. B. Williamson	Howard E. Enders	P. A. Tetrault	F. B. Wade	Wm. M. Blanchard.
†1918–1919	E. B. Williamson	Howard E. Enders	P. A. Tetrault	F. B. Wade	Wm. M. Blanchard.
1919–1920	H. L. Bruner	Howard E. Enders	R. E. Holman	F. B. Wade	Wm. M. Blanchard.
1920–1921	Howard E. Enders	Walter N. Hess	Harry F. Dietz	F. B. Wade	Wm. M. Blanchard.
1921–1922	F. M. Andrews	Walter N. Hess	Harry F. Dietz	F. B. Wade	Wm. M. Blanchard.
1922–1923	Charles A. Behrens	Walter N. Hess	Flora C. Anderson	Harry F. Dietz	Wm. M. Blanchard.
1923–1924	C. C. Deam	Flora Anderson	Marie Bell	Harry F. Dietz	Wm. M. Blanchard.

*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic.

The Town Hall of Brookville, Indiana, the birthplace of the Indiana Academy of Science.

MINUTES OF THE SPRING MEETING, 1923.

BROOKVILLE, INDIANA.

The Spring Meeting of the Academy this year not only afforded its members the opportunity to visit the birthplace of the Academy, but also the opportunity to pay a tribute of respect to one of its most distinguished members, Mr. Amos Butler, who was largely instrumental in founding the society.

The very pleasant time which the members enjoyed was largely made possible through the efforts of the Kiwanis Club of Brookville, and especially its distinguished member, Mr. John P. Goodwin.

The meeting was planned to occupy three days: Thursday, Friday, and Saturday, May 10, 11, and 12, 1923.

Seventy-nine members and eighteen guests were in attendance at the meetings and on the trips.

THURSDAY, MAY 10.

Members of the Academy assembled at the Valley House, Brookville, during the late afternoon and after a brief visit went in automobiles to Magnesia Springs Summer Resort, about two miles east of Brookville, where dinner was served to about 80 members and friends. Following the dinner the party returned to Brookville for the evening meeting which was held in the city hall.

Mr. John C. Shirk gave a most interesting address on the subject of "Brookville and Its Contribution to the Intellectual Life of the State".[1]

Clyde A. Malott gave a short talk on the "Geological Aspects of Brookville and Vicinity".

Stanley Coulter discussed briefly the subject of "Changes in Indiana Flora".

Amos Butler gave a very interesting talk on "Reminiscences of Early Academy Days".[2]

Wm. M. Blanchard concluded the program by reading letters from men who were active in the early days of the Academy, including the following:

David Starr Jordan.
B. W. Evermann.
J. M. Coulter.
Childs W. Hardy.

Amos Butler announced the plan of the field excursions for the following day. He stated that Dr. Case and Harry Stupes would act as guides on the trips.

[1] Published in full on page 19 of this volume.
[2] Published in full on page 14 of this volume.

FRIDAY, MAY 11.

The party assembled at the Valley House Hotel at 9:00 A. M. and together with citizens of Brookville as guides, went in automobiles to the eastern part of Franklin County and from there to Boundary Hill. Due to heavy rain several of the party spent the forenoon at the hotel in reminiscence of days in South America and elsewhere.

In the afternoon other trips were taken including Cedar Grove, the historic Cedar Grove Church, and the beautiful country along the Whitewater River.

After a sumptuous chicken dinner at Mound Camp the party returned to Brookville to enjoy an illustrated lecture by Prof. C. H. Eigenmann on "Explorations and Fishing Experiences in South America".

SATURDAY, MAY 12.

Due to rain and the fact that most of the members came in automobiles no trips were planned for the day and everyone left early for their respective homes. Although the two days at Brookville were very rainy everyone greatly enjoyed the social time together.

BUSINESS SESSION.

BROOKVILLE, INDIANA, May 11, 1923.

A short business meeting of the Academy was called to order by President Behrens following the dinner at Magnesia Springs at 2:00 P. M. Sixty-four members were present.

A letter was read by the secretary from Demarchus Brown, State Librarian, stating that he no longer had room to store the exchanges of the Academy. After some discussion it was voted to refer the matter to the Library Committee for investigation and report at the next winter meeting.

The following 13 names were proposed by the secretary and upon motion they were duly elected to membership:

Coffel, Hal Herbert, Pennville.
Davis, Edna E., Indiana State Normal, Muncie.
Fadely, Leon, Ball Teachers' College, Muncie.
Finster, Ethel B., Indiana State Normal, Muncie.
Frazier, Jesse M., Indiana State Normal, Muncie.
Hargrave, Ellis, 410 E. Third St., Bloomington.
Hill, William J., 322 Kirkwood Ave., Bloomington.
Morgan, Lawrence O., 314 S. Grant St., Bloomington.
Ricketts, Helen E., 3215 Olney St., Indianapolis.
Riecken, William E., 515 Smith Ave., Bloomington.
Robertson, Leo Fred, 521 S. Grant St., Bloomington.
Shirk, John C., 1100 Main St., Brookville.
Spangler, Iva, Indiana State Normal, Muncie.

The following resolution was presented by Wm. M. Blanchard:

Resolved, That we as members of the Indiana Academy of Science express to the Kiwanis Club and to the citizens of Brookville our ap-

preciation for their hearty co-operation and helpfulness in making this annual field meeting a fitting memorial of the birth of the Academy here 37 years ago.

W. M. BLANCHARD,
E. B. WILLIAMSON,
Committee.

President Behrens then turned the meeting over to a round-table discussion of the "Problem of the Conservation of Wild Life". Among those that took part in the discussion were D. M. Mottier, H. S. Jackson and Amos Butler. At the close of the discussion the following committee was appointed to investigate and propose means best feasible for the preservation of the wild flowers of the state: D. M. Mottier, M. W. Lyon, H. S. Jackson, C. C. Deam.

Adjourned at 2:45 P. M. to attend the afternoon field trip.

WALTER N. HESS,
Secretary.

CHAS. A. BEHRENS,
President.

EARLY HISTORY OF THE INDIANA ACADEMY OF SCIENCE.

AMOS W. BUTLER, Indianapolis.

When a youth I was very much interested in animate nature. Books were scarce. I soon learned of the interest in Natural History of Dr. Rufus Haymond. He was very helpful to me in acquiring a knowledge of the more common animals. As I grew older I found there were a few other persons in the community who had similar tastes. Later a few persons interested in Natural History used to get together and talk over scientific subjects. Among those were Edgar R. Quick, Oscar M. Meyncke, Charles F. Goodwin, Rev. David R. Moore, Clifford R. Case and Amos W. Butler.

Rev. Moore had arranged for occasional lectures in the Presbyterian Church. Some of them were on scientific subjects. About this time Moore and I discussed the possibility of organizing a local scientific society. Receiving encouragement from others, a meeting was called to consider the subject. The following persons met January 12, 1881, at the residence of Rev. Moore: Edgar R. Quick, Charles F. Goodwin, John E. Rehme, T. H. Barton, Clifford R. Case, Amos W. Butler. The Brookville Society of Natural History was formed. The following officers were elected:

Rev. David R. Moore, President.
Charles F. Goodwin, Vice-President.
Amos W. Butler, Secretary.
Edgar R. Quick, Correspondent.
John E. Rehme, Treasurer.

A committee was appointed to draft a constitution and by-laws, composed of Messrs. Butler, Quick and Barton.

The second meeting was held January 21, 1881. A constitution was adopted. Departments were specified and curators were chosen. At that meeting Frank Barton, Oscar M. Meyncke and L. D. Dillman joined the original members.

In the fall of 1881 I attended the meeting of the A. A. A. S. at Cincinnati and the succeeding year its meeting in Montreal. At these two meetings I met practically all the leading scientific men of the country—as a boy would meet them. They were very kind to me and many of them showed me special favors. Among those I recall were George J. Brush, president of the Cincinnati meeting; Wm. J. Dawson, president of the Montreal meeting; Harvey W. Wiley, David Starr Jordan, Asa Gray, James D. Dana, Otis T. Mason, Frederick W. Putnam, Major J. W. Powell, C. V. Riley, F. W. Clarke, W. W. Dudley, Alexander Winchell, N. H. Winchell, James Hall, T. Sterry Hunt, Wm. Saunders, E. D. Cope, Edw. S. Morse, Simon Newcomb, O. C. Marsh, T. C. Mendenhall, and many others. Some of them afterwards came to Indiana and took part in its scientific activities. The thing that im-

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

pressed me most was the friendliness of these distinguished men, their interest in a beginner and their genuine desire to be helpful.

For many years after, I attended regularly the meetings of the American Association. Now I am one of the oldest members and fellows.

In my endeavor to obtain information on zoölogical subjects I corresponded with a number of scientific men in the state. The results were often unsatisfactory. I found the experience of other Indiana men was the same. So I began thinking of some way to bring those interested in science in the state together to get acquainted and exchange experiences. To that end correspondence was undertaken with John M. Coulter, Charles R. Barnes, Daniel Kirkwood, T. A. Wylie, David Starr Jordan, Stanley Coulter, R. B. Warder, Philip S. Baker, O. P. Jenkins, David W. Dennis, J. P. D. John, Richard Owen and others. From most of these came favorable responses. Others wrote discouraging replies. In 1885 I attended the meeting of the A. A. A. S. at Ann Arbor. There I first met John C. Branner, then fresh from the work of the Imperial Geological Survey of Brazil, where he had rendered valuable service. He had been elected head of the Department of Geology at Indiana University. Upon mentioning my idea of a state society, he strongly approved it and volunteered his assistance. We took up the subject with other men present from this state. They also encouraged the project. It was finally suggested that the subject be taken up with the Brookville Society of Natural History, as the most active scientific society in the state and that it be requested to call a state meeting of those interested in science and also to appoint a committee to have charge of the details. The Brookville Society endorsed the proposal and appointed a committee: David R. Moore, its president; Amos W. Butler and S. P. Stoddard, to make all necessary arrangements. The meeting was held in the Marion County Court House, December 29, 1885. About 40 persons attended. Dr. J. P. D. John was called to the chair. A permanent organization was effected, with David Starr Jordan, president; Amos W. Butler, secretary. A constitution and by-laws were adopted. A program of papers presenting the knowledge of that time of different departments of science in Indiana was carried out. There were papers by William H. Ragan, Edgar R. Quick, Richard Owen, David Starr Jordan, John M. Coulter, J. P. Naylor, O. P. Jenkins, O. P. Hay, P. S. Baker, Maurice Thompson, Ryland T. Brown, R. B. Warder, David R. Moore, John B. Conner, Amos W. Butler, J. T. Scovell, Daniel Kirkwood. All the above persons were present and read their papers, except Richard Owen and Daniel Kirkwood. Their papers were read by others.

It was decided to hold two meetings a year—the annual meeting in the winter and a field meeting in the spring. By vote, the first spring meeting was set for Brookville, the following spring. That meeting was held May 20-22, 1886—37 years ago—and here are the members of the Indiana Academy of Science to hold another spring meeting where that organization had its conception. Not many of us were at that first spring meeting. Robert Hessler and Amos W. Butler are the only persons present who attended the first spring meeting at Brookville in 1886. But it is the hope that all of you will be charmed

by the beauties of Brookville and that you will hereafter come more frequently.

There were 33 persons registered at the first meeting. Unfortunately the roster has been lost. The following were among those who attended the spring meeting 37 years ago:

David Starr Jordan, Bloomington.
John C. Branner, Bloomington.
Jerome McNeill, Bloomington.
R. L. Green, Bloomington.
M. W. Fordice, Bloomington.
Philip S. Baker, Greencastle.
Oliver P. Jenkins, Greencastle.
David W. Dennis, Richmond.
Albert Porter, Richmond.
J. F. Thompson, Richmond.
Fletcher M. Noe, Indianapolis.
Robert Hessler, Connersville.
Edw. A. Enos, Connersville.
Cal. O. Enos, Connersville.
H. E. Ludwick, Connersville.
T. H. Barton, Connersville.
W. P. Shannon, Greensburg.
Charles W. Hargitt, Greensburg.
John E. Rehme, Brookville.
Edward Hughes, Brookville.
Oscar M. Meyncke, Brookville.
John G. Chafee, Brookville.
Edgar R. Quick, Brookville.
David W. McKee, Brookville.
Amos W. Butler, Brookville.
Charles F. Goodwin, Brookville.
Rev. David R. Moore, Brookville.

Some of us recall a few of the events of that first field meeting—how we were disappointed that John M. Coulter was unable to be present for one of the principal addresses; how well his place was filled by David W. Dennis; that Evermann and others of the Indiana University crowd drove through in a carriage and on the way made a collection of the fishes in the western part of Franklin County. We had no Kiwanis Club to make such splendid arrangements as have been made for this meeting, but the Society of Natural History and its friends did the best they could. The sessions were held in the town hall. On the evening of May 20, 1886, was the following program:

Dr. David Starr Jordan in the chair.
Prayer—Rev. D. R. Moore.
Welcome—D. W. McKee, President Brookville Society of Natural History.
Response—David Starr Jordan.
Address—J. C. Branner.

The next evening, May 21, 1886, the following was the program:

Dr. David Starr Jordan presiding.
Prayer—Rev. J. G. Chafee.
Addresses—
David Starr Jordan.
D. W. Dennis.
P. S. Baker.

The first day was spent among the hills and along the East Fork of Whitewater to Templeton's Ford. Near there, luncheon was served in picnic style. In the deep water above the ford the members of the Academy went swimming. There, as Dr. Dennis said, the members saw each other as they were, a thing they had never done before. There Jordan climbed upon a rock just below the surface of the water and formally christened the Academy. "For," said he, "when the members of the Academy can all go swimming together, it is bound to be a success." There Hessler first came in contact with scientific men and determined to be a scientist. Before going home he discussed with Jordan the question of his going to Indiana University. Altogether, it was a delightful meeting and it brought inspiration and enthusiasm to the members of the local Society of Natural History.

Other spring meetings have been held that are ever to be remembered. Those at Bloomington, where the University made our visit very pleasant. The one to Wyandotte Cave; we drove from Orleans to Paoli, for the first night meeting. Next morning we were up early to get the carriages for the drive to the Cave. Various things happened. Among others, we lost our way so did not reach our destination until mid-afternoon. Having eaten nothing since breakfast and the meal hour being past, we had to take what we could get. I broke out with chickenpox on the way and presume I spread it over most of that part of Indiana. Some thought that having arrived so late it would be necessary to wait until the next morning to explore the cave. It was explained they could see the cave as well by night as by day. When the Sulphur Spring was reached there was no drinking vessel. One must kneel and drink from the basin or lift the water in his hands. One swallow was enough for Professor Karstens. "Oh, my, oh, my," he uttered, "hasn't some one something to take the cruelty out of the water?"

Didn't we have a good time at Maxinkuckee and at Manitou? At Richmond, where the Ohio Academy met with us, and at Oxford, Ohio, where we met with the Academy from that state? Wasn't that a splendid meeting at Greencastle, and how fine was the one at Terre Haute. One that will ever be remembered was the first one at Waveland. Mendenhall, Waldo, Jordan, Jenkins and others, were at their best. How when the herpetologists gathered the first morning at Shades of Death they began to inquire of the owner where they could be most likely to find snakes. He replied there were no snakes there; they had all been killed. Two hours later in their sacks the herpetologists had collected at least a bushel of reptiles to the horror of the proprietor. At Waveland we had a peanut feast. A 50-pound flour sack full of fresh roasted peanuts were eaten in front of the hotel. Those

who came on the three o'clock train the next morning located headquarters by the pile of peanut shells off the sidewalk. Maurice Thompson was there with his gun. He was trying to get specimens of two species of woodpeckers to study the anatomy of their tongues. One, the Flicker, he maintained had the tongue bones poorly developed, while the other, Picus, he said, had the bones so long that they passed over the head to the ear. The sensations produced by the movement of an insect larva in a tree were conveyed to the ear, when the bill was pressed against the trunk. Thereby the bird was able to locate his game and "go for him". Jenkins was not satisfied with his explanation—or pretended not to be. He addressed the Academy, explaining his perplexity, and said, "Mr. President, as near as I can make out, it is like a person trying to smell a rotten apple through a knitting needle stuck in his ear". The speaker evidently became offended at the discussion, for so far as I recall he never again attended a meeting. One has to know how to take these scientists.

All in all, the spring meetings are among our most valuable ones. They afford an opportunity for acquaintance and fellowship that the more formal ones do not.

From the small group that met here 37 years ago, the Academy has steadily grown. Its members are spread over the whole world. Where can one go where they are not? Our organization is highly regarded in the scientific world. Many times have I heard it spoken of by leaders in the scientific field as the best of all the state academies of science.

Here we are, back to the place where it originated—to Brookville—hail and all hail.

BROOKVILLE AND ITS CONTRIBUTION TO THE INTELLECTUAL LIFE OF THE STATE.

JOHN C. SHIRK, Brookville.

I have been asked to give a fifteen minutes talk this evening on Brookville and its contribution to the intellectual life of the state.

It is hard to do justice to the subject in the time allotted. It is 120 years since the first white settler came to Brookville. The hardy pioneers, the brighest and best manhood of the eastern states came down the Ohio River. It was necessary to follow and locate along streams where there was plenty of water power. After they had passed Cincinnati they found the big Miami River to be the first stream coming in from the north. This they followed for five or six miles to the northeast where they discovered a beautiful and enchanting stream coming in from the north, this they called the White Water. They followed it about 25 miles when they came to two forks of near equal size coming together in a beautiful valley with verdant hills beyond and on every side. It seemed to them a paradise on earth. Here in 1803 came Amos Butler, the grandfather of our honored guest this evening, the founder of the Indiana Academy of Science.

Amos Butler, Senior, built his cabin just north of where the Hermitage now stands and soon had built a flour mill on the river bank near by. Here he supplied the early settlers with flour.

In 1808 Amos Butler and Jesse B. Thomas first platted Brookville. The little town soon became quite thrifty. In the year of 1820 a United States land office was located at Brookville and continued there until 1825 when it was removed to Indianapolis, which was quite a calamity to Brookville.

On the 9th of January, 1836, a bill passed both houses of the State Legislature authorizing the building of the White Water canal. It was a gala day in Brookville and was celebrated with a parade, bonfires and booming of cannon all through the night. On the 13th of September, 1838, the ceremony of breaking the ground was celebrated in Brookville. Governor Noble, Ex-Governor Ray, David Wallace and others made addresses. James Finley, editor of the Richmond Palladium, gave the following toast: "There is not in the wide world a valley so sweet—As the vale where the branches of the White Water meet".

When the canal was completed as far as Brookville the town had quite a boom and the people were quite happy. But when the canal was built on to Connersville and Cambridge City and Brookville ceased to be the head of navigation, the town lost much of its importance. But the canal was a great convenience and our fathers boasted of how nice it was when they could board a canal boat at Brookville in the evening, arrive in Cincinnati the next morning, spend the day there and again take the boat, enjoy a good night's sleep and wake up on the morning of the third day back in Brookville. Then it took two nights and a day to make the trip to Cincinnati, now we make it in about one hour and one-half each way on the road.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

The canal continued to operate through many vicissitudes on account of floods and dams washing out until 1866, when it was compelled to give way to the railroad.

Brookville has had its ups and downs, gaining slowly in population at the rate of about 150 each decade during the last one-half century.

Brookville has had many prominent men live in it. In fact it was not uncommon for its citizens to speak in rather a boastful way of the great men who have gone out from Brookville. One day one of our citizens was telling a prominent Cincinnati banker the names of the prominent men who had gone out from Brookville. The banker said: "Well, Charlie, the great men all left Brookville, didn't they." In later years the people of Brookville and Franklin County began to minimize their importance; at least that is what the state tax board seemed to think when it added 30 per cent to the taxable property of the county.

So many names of prominent men have been attributed to Brookville, many of whom lived in Brookville for so short a time they could scarcely be called residents and others never lived there. But there are many who unquestionably lived in and were a part of the daily life of Brookville.

When Indiana became a state in 1816, there were three men living in Brookville who were destined to become governors of the state. They were James B. Ray, 1825 to 1831; Noah Noble, 1831 to 1837; David Wallace, 1837 to 1840; so Brookville furnished the state with governors for fifteen consecutive years. Abram A. Hammond, lieutenant governor was acting governor from 1860 to 1861. Will Cumback, born in Mt. Carmel, was lieutenant governor from 1867 to 1869. General Lew Wallace was at one time governor of the Territory of New Mexico. John P. St. John, Governor of Kansas; William Henson Wallace, Governor of Idaho; Steven S. Harding, Governor of Utah; James Noble, a brother of Governor Noble, became a United States Senator, he served in the Territorial Legislature, in the Constitutional Convention of 1816, and was elected to the first Legislature from Franklin County, he was elected at the first session of the legislature to a seat in the United States Senate, which he held until his death in 1831. Robert Hanna of Franklin County was appointed by Governor Ray to fill the vacancy in the Senate caused by the death of Noble. John Henderson was United States Senator from Mississippi.

James N. Tyner was Postmaster General under President Grant, and James Clarkson was selected as his assistant. Later Clarkson became the Collector of the Port of New York and Chairman of the Republican National Committee. Charles F. Jones was United States Attorney before the Spanish Treaty Claims Commission following the Spanish-American War, in which position he saved the United States many millions of dollars. He is now the first Assistant to the Attorney General of the United States. Dr. John R. Goodwin was Chief Disbursing Officer of the United States Treasury. George E. Downey, once editor of the Brookville Democrat, was Comptroller of the United States Treasury. General Lew Wallace was Minister to Turkey; Edwin Terrell Minister to Belgium, and George C. Hitt was Consul to London.

Franklin County furnished three judges on the Supreme Bench of

Indiana: Isaac Blackford, John T. McKinney and Steven C. Stevens. Rear Admiral Oliver S. Glisson spent his early life in Brookville until he was appointed midshipman in 1826. Captain William H. Herndon, father-in-law of President Chester A. Arthur, lived in Brookville. General Pleasant Hackleman born across the river a short distance below Brookville was the only general from Indiana who lost his life in the Civil War.

The Hermitage at Brookville has been for 25 years the home of John Ottis Adams, one of Indiana's leading artists. Mrs. Adams is also an artist of ability. T. C. Steele made Brookville his home for a time until after the death of his first wife. John Herron, who gave Indianapolis the John Herron Art Institute, spent most of his life in Franklin County where he made brick and tile and did general farming.

Brookville has furnished a number of prominent educators: Dr. John P. D. John, President of Brookville College, Moores Hill College and DePauw University; Charles N. Sims, Chancellor of Syracuse University; William M. Daily, President of Indiana University; Russell B. Abbot, President of Albert Lee College; J. H. Martin, President of Brookville College, and later of Moores Hill College; Charles W. Lewis, President of Moores Hill College and later President of Wyoming State University; L. D. Potter, President of Glendale College; George A. Chase, President of Brookville College; E. H. Barber, Educator in the University of Nebraska; William R. Goodwin, President of Brookville College, also a prominent minister; John W. Locke, President of Brookville College and minister. Many other prominent ministers have lived in the county, among them Joseph Tarkington, James Haven, Thomas H. Lynch, Thomas A. Goodwin and John G. Chafee, minister and poet.

James B. Eads of Mississippi Jetties fame lived in Brookville where his father kept a store. Frank B. Wynn, President of the Indiana Medical Society, of the State Historical Commission and naturalist, was born in Franklin County.

Of writers Brookville claims a goodly number. General Lew Wallace, who wrote Ben Hur, is the best known; Maurice Thompson wrote Alice of Old Vincennes; Louisa Chitwood, who died before she was twenty-three, left more than a thousand poems; Sarah T. Bolton, Frances Conwell Wilson and her husband Forsythe Wilson, Ida Husted Harper, and there are many others who might be mentioned.

James Raridan, John Test, R. B. F. Pierce and Isaac Clements were congressmen who have lived in this county.

I have mentioned some of the prominent people who have lived in Franklin County. Their influence on the intellectual development of the state must be very great. Then there were thousands of hardy pioneers and their children who moved from Franklin County and have permeated almost every part of the state. There is no question of the sturdy manhood and intellectual character of these early pioneers nor that their lives left a strong imprint on the intellectual development of the state.

The Brookville College from 1853 to 1873 did a great educational work.

Far be it from us to admit that all of the great men left the county, they are here in countless numbers, but modesty prevents us from mentioning any names.

There is one name that I have not dwelt upon whom we are proud to honor. It is Amos W. Butler, naturalist, scientist, ornithologist, and for 25 years the most efficient Secretary of the Board of State Charities. Dr. Butler has an international reputation along the lines of his work. We are delighted to have him with us this evening.

WINTER MEETING.

PROGRAM OF THE THIRTY-NINTH ANNUAL MEETING

OF

THE INDIANA ACADEMY OF SCIENCE

HELD AT

DEPAUW UNIVERSITY, GREENCASTLE.

December 6 to 8, 1923.

PROGRAM COMMITTEE.

WM. M. BLANCHARD. C. M. SMITH.
CLYDE A. MALOTT.

THURSDAY, DECEMBER 6, 1923.

8:00 p.m. Meeting of the Executive Committee.
Reports of Committees.

FRIDAY, DECEMBER 7, 1923.

10:00 a.m. General Session.
General Business Session.
Presentation of Papers of General Interest.

A Study of Locomotive Whistles.....Arthur L. Foley
*The Southern Ute Indians of the Pine River Valley, Colorado.....Albert B. Reagan
Geographic Variations in Indiana in Typhoid, Tuberculosis, Cancer and in Total Deaths .....S. S. Visher
A Plea Against Over-Standardization in Scientific Education .....E. G. Mahin
President's Address: Bacteriology and Its Practical Significance.....Charles A. Behrens

2:00 p.m. Sectional Meetings.

BOTANY—ZOOLOGY.

Does *Allium vineale* L. Produce Seeds in Indiana? .....A. A. Hansen
Recent Indiana Weeds.....A. A. Hansen
A Weed Survey of Indiana.....A. A. Hansen
Indiana Fungi—VII.....J. M. Van Hook
Plants New or Rare to Indiana—XII...Chas. C. Deam
Culture Methods in the Production of Polyembryony in Certain Ferns (Polypodiaceae)..D. M. Mottier
*Behavior of Fern Prothallia under Prolonged Cultivation.....D. M. Mottier

* Papers starred not published in this Proceedings.

*Plant Relations in Brazos County, Texas..... ..... Elmer Grant Campbell
*The Trees of Vanderburgh County.....A. J. Bigney
Some Soil and Water Reactions in the Dunes Region of Porter County.....M. W. Lyon, Jr.
Notes on Grasses.....Paul Weatherwax
Indiana Plant Diseases, 1923.....Max W. Gardner
Nitrate Studies on Purdue Rotation Field No. 6 .....I. L. Baldwin, W. J. Nichter, R. O. Lindsey
Notes on Greenhouse Culture Methods Used in Rust Investigations.....E. B. Mains
Plants of White County—VI.....Louis F. Heimlich
*Notes on the Life History of the Snapdragon Rust, *Puccinia antirrhini*.....E. B. Mains
*An Ecological View of Wet Waste Land..... .....Blanche McAvoy
*Preliminary Notes on Comparative Growth in Grazed and Ungrazed Woodlots at Purdue .....Burr N. Prentice
*A New Station for *Tipularia discolor* (Pursh) Nutt.....Ray C. Friesner
*The Relations of Vegetation to Bird Life in Texas .....Harry C. Oberholser
Notes on the Functions of the Forceps of Earwigs .....W. P. Morgan
*A Seven Somite Human Embryo.....F. Payne
A Study of the Productivity and Breeding Habits of the Bluegill, *Lepomis pallidus* Mitchill .....Lowell Thelwell Coggeshall
The Relation of Size to Age in Some Common Freshwater Fishes.....Home R. Bolen
The Diurnal Oxygen Pulse in Eagle (Winona) Lake ..... Will Scott
*An Analysis of the Contribution of Hyalella to the Economy of a Lake.....Will Scott
*The Morphometry of Eagle (Winona) Lake.Will Scott
New Records of Indiana Mammals....M. W. Lyon, Jr.
*What is the Indiana State Normal School Doing to Promote Public Health?.....R. A. Gantz
Reclamation of Soil by Vegetation.....F. M. Andrews
Midsummer Growth.....F. M. Andrews
Studies on Pollen—IV.....F. M. Andrews
Protoplasmic Streaming .....F. M. Andrews

CHEMISTRY—PHYSICS—MATHEMATICS.

*A Rayleigh Disk of New Design and Increased Pitch Range.....Arthur L. Foley
*A Proposed Phonometer Based on a New Principle.....Arthur L. Foley

* Papers starred not published in this Proceedings.

*Some Untenable Acoustic Theories....Arthur L. Foley
The Power Required to Drive Spoke and Disk Wheels and Pulleys.....Arthur L. Foley and B. Eisenhour
Why the Logarithm in Logarithmic Decrement?.....R. R. Ramsey
The Silent Electric Discharge and Its Effects on Gases.....R. H. George and K. A. Oplinger
The Electrometric Titration of Boric Acid in the Presence of Polyphenols and of Organic Acids.....M. G. Mellon and V. N. Morris
*Calculating the Results of a Volumetric Analysis.....M. G. Mellon
*The Corrosion of Lead Cable Sheath by Indiana Soils.....F. O. Anderegg
*Some Calculations of the Composition of Liquid Water.....F. O. Anderegg
*The Influence of Certain Factors on the Hydrogen Ion Concentration of Milk.....Eli Duncombe
*Some Farm Chemistry I Have Met.....R. H. Carr
*Electrometric Titration of the Vegetable Akaloids.....E. G. Mahin and G. B. Wilson
*Tests of New Alloys for Permanent Magnets.....C. M. Smith
*On the Verification of Lommel's Theory of Diffraction.....Mason E. Hufferd
Familiarizing Chemistry Students with the Gram-Molecular Volume of Gases.....W. M. Blanchard

GEOLOGY—GEOGRAPHY.

*The Lost River Region and a Guide to Its Study.....Clyde A. Malott
*The Deepening and Widening of Valleys.....Clyde A. Malott
*Notes on a Few Cretaceous Species of Western America, Most of Them New to Science.....Albert B. Reagan
*Indian Funerals.....Albert B. Reagan
*Whaling off the Olympic Peninsula of Washington.....Albert B. Reagan
*A West Coast Indian Honeymoon....Albert B. Reagan
*Data on the Use of Indiana Dune Sand for Track Elevation in Chicago.....S. S. Visher
*Geology of the Coal Measures of Indiana..W. N. Logan
A Change of Drainage of Raccoon Creek, Parke County, Indiana.....Glenn G. Bartle
The Development of the Soil Survey....T. M. Bushnell
*A Groundwater Experiment at South Bend, Indiana.....W. M. Tucker

* Papers starred not published in this Proceedings.

*The Fall Creek-Bell Creek Valley, Indiana.....
..... Fred J. Breeze
*The Present Status of Geography.....Fred J. Breeze
A Case of Stream Piracy near Greencastle, Indiana
.....Ernest R. Smith

6:00 p. m. Annual Indiana Academy of Science Dinner.
Social Room of the Presbyterian Church.

7:30 p. m. Concert by DePauw University School of Music.
Orchestra and University Choir.
Courtesy of Dean R. G. McCutchan, Conductor.

8:00 p. m. Illustrated Lecture on the General Subject of Colloids.
Martin H. Fisher, Professor of Physiological Chemistry.
University of Cincinnati School of Medicine.

8:45 p. m. Science in the Government Service.
Address by Harvey W. Wiley, Washington, D. C.

SATURDAY, DECEMBER 8, 1923.

9:00 a. m. Inspection of Buildings and Grounds of DePauw University.

* Papers starred not published in this Proceedings.

MINUTES OF THE BUSINESS SESSION.

DEPAUW UNIVERSITY, GREENCASTLE, INDIANA.

MINUTES OF THE EXECUTIVE COMMITTEE.

December 6, 1923.

The Executive Committee was called to order at 8:05 p. m. in the Physics Lecture Room by President C. A. Behrens. The following members were present: Flora Anderson, F. M. Andrews, C. A. Behrens, A. J. Bigney, W. M. Blanchard, A. W. Butler, W. A. Cogshall, J. J. Davis, H. F. Dietz, H. E. Enders, A. L. Foley, D. M. Mottier, J. P. Naylor, F. Payne, E. B. Williamson, J. S. Wright.

The minutes of last year's meetings were read and approved.

Report of Treasurer.—Treasurer Wm. M. Blanchard reported as follows:

Balance in Treasury, December 4, 1922	$332 57
Dues collected from December 5, 1922, to December 3, 1923	448 05
Total	$780 62
Total Expenditures	257 55
Balance in Treasury, December 3, 1923	$523 07

The bill of the Fort Wayne Printing Company for printing done some time ago was presented. After some discussion, a motion was passed authorizing E. B. Williamson, as agent for the Academy, to reimburse the Fort Wayne Printing Company not to exceed 50 per cent of the original bill.

Report of Press Secretary.—Press Secretary Harry F. Dietz reported that press notices had been sent to all the Indianapolis papers and to the Associated Press.

A discussion of the value of publicity followed. Since the State Academy of Science should be the center of scientific activity and should be the most important influence in developing an appreciation of scientific work within the state, because it is the most representative body of workers, it was suggested by J. J. Davis that the Academy be brought to the notice of more people by securing members from all parts of the state, and by articles in as many of the newspapers of the state as possible. It was therefore recommended that authors be asked to write an information story of one double-space typewritten page to be handed in at the time the manuscript is handed in. The editor could then study the news story as he is editing the manuscript and arrange for their use when the Proceedings is published.

On motion and second the recommendation was adopted.

It was moved that the recommendation be mimeographed and sent to members. Motion passed.

Committee reports were considered as follows:

Relation of Academy to the State.—Wm. M. Blanchard read a letter from Chairman Robert W. McBride expressing regrets that he could not be present on account of a severe accident which deprived him of the use of his right hand. He reported in his letter that "everything is harmonious and no action necessary by the Academy".

Publication of Proceedings.—Chairman J. J. Davis reported that the 38th annual Proceedings was printed and distributed the last of October. The delay was due to priority of legislative printing matter earlier in the year. It was thought that with the co-operation of authors the publication of the Proceedings may be completed not later than March.

Five of the longer papers were not published because the cost of printing would exceed the appropriation. It was suggested that these papers be included in the next Proceedings. Approved.

A list of 27 recommendations made by the editorial committee was read.

It was moved that these recommendations be recognized by the Academy as the "Editor's Code", and that copies of these be sent to all members. Motion carried.

It was moved that the editor have the "Code" mimeographed and sent to all Academy members. Motion carried.

It was recommended that authors desiring reprints be charged at the rate of:

$2.75 per 100 for separates of four pages or less.
$4.10 per 100 for separates of five to eight pages.
$5.50 per 100 for separates of nine to sixteen pages.

The money thus collected to be used to enlarge the Proceedings if found feasible.

After much discussion, it was moved that if it was found legally permissible, a charge be made for reprints as outlined. Motion carried.

PUBLICATION FUND.

By balance from 1921 appropriation	$119 83
By appropriation for 1922 Proceedings	1,200 00
Total	$1,319 83
To disbursements—Publication of 1922 Proceedings	1,282 18
Balance	$37 65

Program Committee.—Chairman Blanchard stated that preliminary announcements and final programs had been sent to members; that papers which seemed of more general interest had been placed on the morning program; that Prof. Martin H. Fischer of Cincinnati and Dr. Harvey W. Wiley of Washington, D. C., had been secured for the evening program; and that after the annual dinner which would be served in the Presbyterian Church, Dean R. G. McCutchan would direct a half hour concert by the orchestra and choir of the DePauw Uni-

versity School of Music. The sectional meetings would be held as previously, except that on account of the large number of papers, Botany and Zoölogy would hold their sessions separately.

It was moved that the treasurer be authorized to pay the expenses of Professor Fischer of Cincinnati and one-half of the expenses of Doctor Wiley of Washington, D. C. Motion carried.

Biological Survey.—No report.

State Library.—Chairman Amos W. Butler stated that publications are coming in regularly and are being catalogued and placed on the shelves. Foreign ones are coming in again. No binding has been done within the last year because of lack of funds and the incompleteness of volumes.

It is urged that members make use of the valuable collections—many of which are not found elsewhere.

Distribution of Proceedings.—Acting Chairman Harry F. Dietz reported that the 1922 Proceedings were mailed the last of October and that, so far, only 15 had come back on account of wrong address.

He stated that there are 250 on the exchange list in this country and some foreign countries, so only a comparatively few copies are left out of the 900 printed.

Membership.—Acting Chairman Paul Weatherwax reported there were 45 names to be presented tomorrow.

Auditing.—Chairman H. E. Enders reported that the treasurer's report had been audited and found correct.

Advisory Council.—No report.

Research Committee.—Secretary John S. Wright reported that on March 23, 1923, at the call of the Chairman, A. L. Foley, all members of the committee met in Indianapolis. After full discussion of the work that might be accomplished, the following resolutions were passed:

Whereas, several colleges in Indiana have lately organized graduate departments and have provided first class facilities for research work in certain fields of science, and

Whereas, recognition from research committees and councils outside the state would be a very potent factor in inaugurating this work on the increased scale for which the institutions have planned and prepared, therefore be it

Resolved, that we, the Research Committee of the Indiana Academy of Science, in behalf of the Academy and the future of the State of Indiana in the field of investigation, respectfully petition the Charles A. Coffin Fellowship and Research Committee to take cognizance of the facts as above set forth, by granting a few research fellowships to Indiana institutions in case worthy candidates make application for them.

The above resolutions were transmitted to Dr. Frank B. Jewett, care of The American Institute of Electrical Engineering, 33 W. 39th St., New York City, and duly acknowledged.

Similar resolutions were adopted and forwarded to the National

Research Fellowship, care of Dr. W. E. Tisdale, Executive Secretary of the Research Fellowship Board, 1701 Massachusetts Ave., Washington, and duly acknowledged. Up to date nothing more has been done than to canvass the field and its possibilities.

Academy Foundation.—Chairman Amos W. Butler gave the following report:

ENDOWMENT FUND FOR RESEARCH.

1922		
December 8	—Balance on hand	$33 31
December 15	—Interest Victory Loan Bonds	7 14
1923		
January 1	—Interest R. R. Building and Loan Association	3 00
July 1	—Interest R. R. Building and Loan Association	3 00
July 1	—Interest Victory Loan Bond	2 04
July 1	—Interest, $200 U. S. Treasury note, 4½% to December 15, 1923	9 00
		$57 49

OTHER ASSETS.

Received Victory Loan Bond, $100.00.

December 1	—Invested in 6% R. R. Building and Loan Stock.	$100 00
December 1	—Invested in 6% R. R. Building and Loan Stock.	$100 00
December 1	—U. S. Treasury notes, 4½%	200 00
		$400 00
December 1	—Balance, cash on hand	57 49
	Total balance on hand	$457 49

Archeological Survey.—Chairman W. N. Logan reported that a survey of the coal resources had been conducted in Gibson, Knox, Pike and Posey counties; and in some of these counties archaic deposits were found. Section maps of more than one-half of the counties of the state had been prepared for use by county historical clubs and others for location of archeological points of interest in various counties.

There is urgent need of a law in Indiana which will prevent the destruction of the few remaining archeological objects of interest.

Special Committee.—Chairman D. M. Mottier reported for the committee appointed to investigate and propose methods best feasible for the protection of the wild flowers of the state, that it is the sense of the committee that certain wild plants be protected and conserved. The report points out ways by which this may be done, quotes laws protecting wild plants in Illinois and Vermont, and proposes a law for Indiana. It was decided that this report should be read at the business session tomorrow.

Old Business.—It was moved that the treasurer be empowered to turn over to the research fund such an amount as can in his judgment be spared. Motion carried.

New Business.—The question of the Indiana Academy of Science affiliating with the A. A. A. S. was brought up and discussed.

It was moved that a committee consisting of the president, secretary and treasurer be authorized to take steps to affiliate the Academy with the A. A. A. S. at the Christmas meeting of the A. A. A. S., if, on investigation, nothing was found to be disadvantageous to the Academy. Motion passed.

It was announced that those in the state interested in entomology who met at Lafayette October 26, 1923, decided to meet annually the day before the Academy meetings and at the same place as the Academy. The Academy was asked to announce these meetings in their regular announcement. Anyone interested in insects is invited to attend.

It was recommended that the following be presented to the Academy for election to fellowship: Flora Anderson, M. W. Gardner, W. N. Hess, W. M. Tucker and T. G. Yuncker. Recommendation adopted.

It was moved that the Secretary be instructed to write Judge R. W. McBride expressing for the Academy their thanks, sympathy and hopes for a speedy recovery. Motion passed.

A letter from Dean Stanley Coulter inviting the Academy to meet at Purdue University next fall was read. The invitation was accepted by consent.

Meeting adjourned at 11:30 p. m.

MINUTES OF GENERAL SESSION.

10:00 a. m., December 7, 1923.

Business Session.

The meeting was called to order by President Behrens.

The minutes of the Executive Committee were read and with the exception of those pertaining to affiliation with the A. A. A. S. were approved.

After some discussion on the question of affiliation, it was moved that the action of the committee last night in regard to the affiliation of the Academy with the A. A. A. S. be approved. Motion carried.

The report of the committee on Preservation of Wild Flowers in the state was read, and after discussion of the report it was moved that the committee on Preservation of Wild Flowers be continued and be empowered to call in such aid as it saw fit. Motion carried.

The letter of invitation from Stanley Coulter to hold the next winter meeting at Purdue University was read. It was moved that the invitation to hold the winter meeting at Purdue University be accepted. Motion carried.

Amos W. Butler read the following resolution:

In view of the fact that many of the mounds, earthworks and other valuable and interesting remains of the Indians have been destroyed and most of the others are in danger of destruction, and

In view of the further fact that a large part of the objects representing the life of the Indians have passed into the hands of commercial collectors and many of them have passed out of the state to other states and countries and are therefore probably lost to us forever,

Therefore, be it resolved, that the Committee on Relation of Academy to the State be authorized and directed to attempt to secure legislation for the protection and preservation of such sites and objects. Passed.

The Membership Committee proposed the following named persons for membership. On motion they were duly elected:

Adams, Esther, 5244 Burgess St., Indianapolis.
Anthony, Harvey M., Anthony Bldg., Muncie.
Ayres, Agnes W., 1003 State St., West Lafayette.
Bartle, Glenn Gardner, 218 W. Market St., New Albany.
Beck, Carol Harriet, R. R. J, Lafayette.
Blaydes, Glenn W., Roachdale.
Bloye, Amy Irene, 115 E. Columbia St., West Lafayette.
Brandt, Helen Rowan, 2234 High St., Logansport.
Christie, George Irving, 607 University St., West Lafayette.
Cummins, John A., Indiana Central College, Indianapolis.
Davis, Harold Thayer, 613 S. Henderson St., Bloomington.
Elliott, Edward Charles, 515 S. Seventh St., Lafayette.
Finley, George W., 18 E. National Ave., Brazil.
Flemion, Florence D., 301 E. Kirkwood Ave., Bloomington.
Frey, Franklin E., 222 Ohmer Ave., Indianapolis.
Friesner, Mrs. Gladys M., 5360 Julian Ave., Indianapolis.
Gage, George R., 112 Bloomington St., Greencastle.
Gamble, Mary Edith, 120 Chauncey Ave., West Lafayette.
Garrard, Herbert L., 216 Waldron St., West Lafayette.
Goodale, Charles DeLoss, 221 Waldron St., West Lafayette.
Hammond, Alyce L., Glendale Park, Hammond.
Harding, Wilbur R., 128 Andrew Place, West Lafayette.
Harger, Rolla Neil, 3913 Kenwood Ave., Indianapolis.
Hargitt, Thomas F., 412 Smith Ave., Bloomington.
Harvin, Glenn Beckham, 108 Waldron St., West Lafayette.
Hayner, Clark Ross, 277½ Littleton St., West Lafayette.
Hunt, Raymond S., 508 E. Third St., Bloomington.
Johnston, Harriet D., 76 Layman Ave., Indianapolis.
Kaley, Leona M., 523 N. Beville St., Indianapolis.
Kellogg, Mary, 124 Marstellar St., West Lafayette.
Kennedy, Glenn DeFore, 266 Littleton St., West Lafayette.
Kinnet, Russell, Milroy.
Leaming, Eleanor Patton, 825 S. Ninth St., West Lafayette.
Loew, Fred A., Huntington College, Huntington.
Loughridge, Gasper A., 407 S. Grant St., Bloomington.
McWilliams, Thelma, 126 Lutz Ave., West Lafayette.
March, Verna Louise, 124 Pierce St., West Lafayette.
Mount, Harry W., 1012 Lexington Ave., Indianapolis.
Neff, Joseph Edgar, 132 S. Scott St., South Bend.
Nester, Henry George, 2832 N. Capitol Ave., Indianapolis.

Newton, Roy C., 434 N. Grant St., West Lafayette.
Otten, Ralph Edward, R. R. No. 2, Rossville.
Parfitt, Eliott H., 318 N. Grant St., West Lafayette.
Phillips, George R., 234 E. Pratt St., Indianapolis.
Poe, Doris J., 1726 E. Washington St., Indianapolis.
Porter, Bennet A., 10 W. Sycamore St., Vincennes.
Priest, Bernice, W. Sixth St., Marion.
Reed, Harry J., Purdue Exp. Sta., West Lafayette.
Reed, Dr. William C., 728 E. Third St., Bloomington.
Rogers, Ruth Anna, 533 N. Grant St., West Lafayette.
Shlensky, Morris Ralph, 450 E. Sibley St., Hammond.
Shrock, Robert R., Bennett's Switch.
Smith, Elmer Gillam, 101 E. Columbia St., West Lafayette.
Smith, Geraldine Frances, 421 University St., West Lafayette.
Switzer, J. Elmer, 1001 Atwater Ave., Bloomington.
Vernon, Sarah Evelyn, Royal Center.
Wagener, Edward F., 1138 Oxford St., Indianapolis.
Watson, Ivan Dale, 417 Waldron St., West Lafayette.
Wilson, Judson D., 429 E. Seventh St., Bloomington.
Zumstein, Reginald B., 810 N. Sixth St., Lafayette.

The Executive Committee recommended the following named persons for election to fellowship. They were elected:

Flora Anderson. W. N. Hess. T. G. Yuncker.
W. M. Tucker. M. W. Gardner.

Chairman Andrews announced the following nominations for officers for 1924:

President, Charles C. Deam, Bluffton.
Vice-President, C. M. Smith, West Lafayette.
Secretary, Flora Anderson, Bloomington.
Assistant Secretary, Marie Bell, Bloomington.
Treasurer, William M. Blanchard, Greencastle.
Editor, J. J. Davis, West Lafayette.
Press Secretary, Harry F. Dietz, Indianapolis.

Chairman Foley reported the recommendations formulated by the Research Committee at their meeting in Greencastle, December 7. It is recommended that the attention of manufacturers who may have technical problems and others who may be interested in financing research be informed of the plans of the committee to aid and advise in the solution of such problems, also of the resources at the command of the members of the Academy that might be utilized in investigation and research.

It is also recommended that a list be made of the members of the Academy who are in a position to co-operate in research work with a statement of their facilities.

It is further recommended that the Academy members be asked to co-operate with the Research Committee in compiling a list of the addresses of the manufacturers of the state and all others who might be interested in the work of the committee.

On motion the report was accepted and the committee continued.

It was moved by A. C. Kinsey that the Secretary address the National Research Council as follows:

(1) That it is the opinion of the Indiana Academy of Science that an annual index of new generic names is a vital necessity to every scientist who in any way wishes to refer to an animal by name; and

(2) That we urge the National Research Council, in view of the threatened failure of *Zoological Record*, to take steps to guarantee the perpetuation of such an index by any means which may seem wise to that council.

Motion carried.

It was moved that a committee consisting of the present and future presidents, secretary and treasurer have a meeting to plan for commemorating the 40th birthday of the Academy. Motion carried.

Business session adjourned at 10:50 a. m.

With two exceptions the papers were given as printed on the morning program. The second paper was omitted due to the absence of the author. Due to the lateness of the hour the last paper—Presidential Address—was postponed till the afternoon session.

The meeting adjourned at 12:30.

The Academy convened at 2:00 p. m. to hear the Presidential Address, after which the sectional meetings were held in the respective rooms.

Ninety-five members and guests enjoyed the dinner prepared by the ladies of the Presbyterian Church at 6:00 p. m.

A vote of thanks was extended to the ladies of the Presbyterian Church for the excellent dinner they had served.

A vote of thanks was extended also to the Program Committee for the successful and enjoyable meeting they had planned.

The evening session was held in Meharry Hall and followed the order outlined on the program.

At 10:00 p. m. the 39th annual meeting of the Indiana Academy of Science closed.

FLORA ANDERSON,
Secretary.

CHARLES A. BEHRENS,
President.

PRESIDENT'S ADDRESS.

BACTERIOLOGY AND ITS PRACTICAL SIGNIFICANCE.

CHARLES A. BEHRENS, Purdue University.

Bacteriology has only recently been recognized as a cardinal science —probably less than fifty years—although the diseases of smallpox, rabies and plague were known hundreds of years before Christ and occurred with the same lesions and characteristc symptoms as they do today.

The first glimpse into its mysteries was simultaneous with the invention of the microscope. The origin of this instrument dates back to the period of the "renaissance"; about the time Harvey discovered the circulation of the blood. The real perfection of the microscope was not accomplished until well into the nineteenth century.

While bacteriology had its inception with the discovery of the microscope and its development for a time kept pace with the perfection of this instrument, the study of bacteria as such, while very important, was of interest only to the microscopist and botanist.

It required such geniuses as Louis Pasteur and Robert Koch to develop methods whereby one could correlate and associate the micro-organisms revealed by the microscope to the phenomena they produced. Thus the establishment of bacteriology as a modern practical science.

If one were to review the early historical development of this subject one would readily note that its forerunners were the ancient ideas of superstition relating to disease; followed by the germ theory; intermingled throughout with the theories of spontaneous generation of life; the development of the compound microscope and the marked stimulus it gave to investigational work in this field; the demonstration of the facts revealing the definite rôle micro-organisms played in fermentation and disease and finally the chemical and physiological developments.

A comprehensive consideration of this extended field is generally termed bacteriology and in practice it is the study of the smallest forms of living matter, e. g., bacteria, yeasts, molds, transitional forms, protozoa and ultra-microscopic organisms (viruses).

However, the subject in its broader scope would be more correctly called microbiology or better protistology. The word protist is about the equivalent of the colloquial term germ and signifies the lowest form of life whether plant or animal. The malaria germ, for instance, is an animal while the pneumonia germ is a plant.

All of these forms are important not only because they induce disease in man and animals but also because they are active in processes of putrefaction and fermentation in dead matter.

The nitrogen of the protein and the carbon of the carbohydrate molecules are by these processes rendered available for plant life which in turn are used by higher animals.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

The life of the higher beings is intimately associated with these smaller organisms; in fact the higher forms would be impossible without the lower ones.

When one recognizes that these micro-organisms are continually at work breaking down dead matter and preparing the way for new life one realizes that they are beneficial and indispensable.

A great practical industrial significance is attached to these one-celled organisms because many of the products, such as the alcohols, acetone, acetic, butyric and lactic acid and other organic compounds to which they give rise are directly utilized by man. In our own State of Indiana we have a mammoth plant which employs the industrious bacteria in the production of organic solvents used in commerce.

The vast deposits of sodium nitrate (soda saltpetre) in South America and the potassium nitrate (saltpetre) of India owe their origin to the action of bacteria on the guano, an excrement of birds.

Bacterial activity occurs to a large extent in the production of foods. Special flavors and characteristics in foods such as butter, cheese, sauerkraut, pickles, ensilage and koumiss are largely due to the desirable fermentative changes which occur.

The dairy industry has been revolutionized within the last few years due to the recognition of the rôle bacteria play in the manufacture of such products. With the knowledge that dairy products may give rise to certain diseases, the cows, as well as those employed in and about milk producing and handling establishments, are examined for certain bacterial diseases of which tuberculosis and latent typhoid fever are outstanding.

It is well known that bacteria develop non-poisonous chemical products, especially resembling certain of the poisonous vegetable alkaloids, when grown upon nitrogenous foods as meats and cheese, as well as in the cadaver. And because of their occurrence therein great importance was attached to them in legal medicine. Until the researches of Selmi revealed this fact undoubtedly convictions of otherwise innocent persons were committed.

It is now a recognized fact that there is practically no such thing as ptomaine poisoning. The ill effects, to an overwhelmingly large per cent, are due to acute infections primarily with *Bacillus enteritidis*, the para typhoid organisms and to the highly poisonous soluble products of bacterial growth (botulinus toxin). This knowledge has taught us how to more intelligently handle and prepare foods.

Micro-organisms also play an important part in the tannery as depilatories, in the bating and the tanning of leather. The flax and hemp industries are dependent upon bacterial activity; and the fermentation of such origin has proved of value in the handling of hay and the curing of tobacco.

Primative man thousands of years ago, although soil bacteriology, of course, was unknown, recognized the value of fertilizers; transfer of rich top soil to new or arid tracts; soil tillage; rotation of crops and green manuring. The members of the bean family were also considered as special soil enrichers.

While this was the practice in those remote times, it was only within very recent years that anything like the true significance of these basic agricultural principles have been discovered. Indeed soil microbiology is far from being understood even today.

We now know that there are (a) bacteria which are normal inhabitants of the soil which render the organic matter (humus) in such form that it is available to the growing plant. These "rotting bacteria" disintegrate the dead plants and animals forming ammonia and other compounds. It was commonly supposed that the nitrogen of the air was worthless unless changed to ammonia by electric storms or similar disturbances. There are (b) bacteria (azotobacter, clostridium) which grow in the soil as well as (c) those that live in symbiotic relationship (radicicola) and are found in the nodules (bacteroides) on the roots of certain plants (legumes) all of which have the property of changing atmospheric nitrogen into an assimilable form for the growing plant. Modern scientific agriculture which results in the increase of soil productiveness must necessarily embody and encourage the growth of these groups of helpful bacteria which elaborate chemical compounds required for proper development of the crop plant and discourage harmful forms of which there are also many.

Proper effective sanitary and public health methods become necessary in view of the fact that the soil harbors, in addition to those that are harmful to lower plants and animals, certain organisms that are pathogenic to higher animals including man, causing diseases such as lock-jaw, tuberculosis, typhoid fever, gangrene, anthrax, foot and mouth disease, lumpy jaw, hook worm and other intestinal parasitic infections. In certain parts of the country proper drainage and tillage of the soil have proven to be very beneficial by removing, as much as possible, the breeding places of mosquitoes which carry malaria and yellow fever.

The selection of a pure water supply and the proper disposal of sewage is of the greatest importance in the conservation of public health. A pure water supply is especially essential in the prevention of such diseases as typhoid fever, dysentery and cholera.

The extermination of pests such as chinch bug, rats, mice, rabbits and squirrels by means of microbes is at present apparently not entirely successful from a practical standpoint. It has, however, possibilities.

In the development of bacteriology the relation of bacteria to disease undoubtedly received the greatest prominence. Especially was this true because, with the discovery of the microscope, bold scientists often unhestitatingly declared that they had seen the germs causing such diseases as plague, syphilis and smallpox.

The germ theory of disease of Kircher of over two hundred years ago, coupled with van Leeuwenhock's observations and finally brought to a crowning climax through the works of Pasteur and Koch, is a thing of the past. Micro-organisms, as has been demonstrated thousands of times, are responsible for a great number of infectious diseases. This positively proven fact is unquestionably an important one and of even greater significance are the results which aid us to scientifically and successfully prevent and combat these diseases.

In the latter fifties, Ignatius Semmelweiss, a physician of Vienna, insisted upon using chlorinated lime for washing the hands and instruments previous to all examinations made in the maternity hospital. As a result deaths from puerperal infection fell from as high as 50 per cent to practically nothing. But he was ahead of his time, was persecuted and died insane. Twenty years later a monument was erected to him by the International Congress of Hygiene.

Years later, in 1867, Lord Joseph Lister, aided by Pasteur's work on fermentation, attempted to prevent infection by removing or actually destroying the causative organism by means of germicides. We are all familiar with the benefits accorded mankind through the practice of Listerism or antiseptic surgery.

METHODS OF INFECTION.

The prevention of infectious diseases as they may occur in sporadic, endemic, epidemic and even pandemic form may be greatly facilitated by taking into account how these organisms enter and later leave the infected animal. How they may be disseminated from individual to individual and how they are perpetuated in nature are also conditions well worth recognizing and of great practical significance.

I. It was formerly thought that germs could not penetrate into the interior of the body through the unbroken healthy skin or mucous membrane. But nowadays we can say with certainty that they can.

It was early found that pus organisms could be rubbed into the skin and cause boils.

Loos, 1902, in Egypt, showed that the hook worm is excreted in the feces, that the larvae are formed in the wet soil and that these larval forms could penetrate the whole skin and go to the intestine. If these relatively large organisms can do this, certainly the smaller, micro-organisms can do likewise.

With protozoal diseases we have a very clean-cut story. In Dourine (mal du coit; horse syphilis), a trypanosomal infection (*Trypanosoma equiperdum*) and also in syphilis in man (*Treponema pallidum*), the mucous surfaces are penetrated and probably it is not necessary to have a lesion.

Novy demonstrated that if the spirochaetes of the relapsing fevers come in contact with the mucous membrane of the eye 100 per cent infection ensues.

The application of the non-motile plague germ to the mucosa of the pharynx is more certain to infect than when injected into the body under the skin.

Fraenkel induced disease by causing the bacillus of tuberculosis to pass through the normal skin.

Probably all motile and non-motile micro-organisms can penetrate the uninjured mucous membrane and perhaps the skin.

II. Infection through the Alimentary Canal. This is closely associated with the previously mentioned avenue of infection. It may occur (a) through contaminated eating utensils; (b) through food contaminated in handling; by growth; by insects such as flies; and (c) by infections through water and milk.

III. Infection through the Respiratory Tract. Examples of this method of infection are: pneumonic plague, pulmonary tuberculosis, influenza, etc. These are infections mainly transmitted through "infective droplets" and "from hand to mouth". This fact was again clearly shown during the last influenza pandemic. An untold amount of suffering, incapacitation, loss of time and money can be avoided by simply guarding against these last two methods of infection ("infective droplets" and "from hand to mouth"). It is recognized that by far the greatest per cent of all infections gain entrance into the body in this way.

IV. Infection through Wounds. In this connection we must consider wounds as ranging all the way from slight abrasions to profound injuries. Slight cuts, accidents and minor operations many times necessitate no particular precautions, but there is always danger of an infection. Major accidents, such as bones crushed, are very productive of infection.

V. Infection through Insects. This source of infection was formerly altogether disregarded but it is now considered very important. The insect may play the part of a passive carrier (non-blood sucking), as the mechanical carrying of infective material by flies. The insect may also make its own wound (puncture) in which case it is blood sucking and is an active carrier of the disease. Malaria and yellow fever, as is well known, are examples of the latter method of infection.

VI. Congenital Transmission of Disease. Here the organism enters the body previous to birth, is present and active in the new born. In the latter eighties almost conclusive proof was given of anthrax passing from an infected cow to the calf and so spread. This was disregarded at the time because it was then held that uninjured tissue could not be penetrated by infective organisms. This view, of course, is no longer held. Especially in syphilis and tuberculosis scores of the still born show this infection.

Avenues of Exit.

Having thus briefly described the natural methods of infection one quite instinctively asks how do germs leave the infected body.

Micro-organisms make their exit in the secretions and through the excretions. The organisms usually tend to localize in certain organs, e. g., the typhoid bacillus in the kidneys, others in the liver, mammary gland, etc.

I. Saliva and Sputum. In hydrophobia (rabies) the salivary glands of the animal are infected and this is the chief manner of exit.

Tuberculosis is the most noted case of exit via the sputum. Pneumonic plague, pneumonia and influenza also are examples of the same.

II. Nasal Discharge. The organisms causing influenza, leprosy, glanders, infantile paralysis and meningitis are found in such discharges.

III. Intestinal Discharge. This is often the chief and only avenue of exit. It is primarily of importance when the organism is multiplying in the intestine, but also when the intestine is penetrated, ulcerated, or the growth is localized as may be the case in anthrax, bacillary as well as amoebic dysentery, typhoid and para-typhoid fever.

IV. Urine. It is almost axiomatic that infections of the blood

settle in the organs and may remain there for some time and then finally pass out through the urine. It usually is secondary to the intestinal route but still very important. This is true of malta fever and may be of tuberculosis, typhoid fever and a host of other diseases. This concerns mostly the kidney.

V. Scaling. Although we do not yet know the specific organism for smallpox and chickenpox, still there is now absolutely no doubt of these diseases being spread from the scabs.

VI. Blood. The blood may harbor bacteria, protozoa (malaria, trypanosomes, etc.), spirochaetes or even invisible unknown organisms (foot and mouth disease). Such blood leaving by hemorrhages or abscesses may spread plague, glanders, anthrax, etc. When a blood sucking insect (fly, tick, flea, mosquito), absorbs infective blood it becomes capable of transferring the infection to other animals. Usually there is a specific carrier for each disease and organism (one species and one genus).

INDIVIDUAL CARRIERS.

The first recognition of an individual carrier was by Pasteur and Sternberg, 1881, in pneumonia. Now it is known that all of us often have some dangerous organism in our mouth. It causes us no harm but later it may reach a susceptible person and start the disease.

Later (in the early nineties) in the study of diphtheria, it was found that convalescents could carry the organism in their mouths for months. Moreover, typhoid fever patients may continue to excrete the bacillus for months and years through the feces and the urine. The same is true of cholera, but usually the dangerous period is much shorter than that of typhoid fever; only a matter of a few weeks.

Again, in spinal meningitis and infantile paralysis, many apparently healthy persons have been shown to have infected nasal discharges.

In the same class is Texas fever of cattle. The animal recovers from the disease but remains a carrier for life.

This principle is nicely illustrated in malta fever. The organism was known for 15 years (1885) before its life cycle was worked out. Investigation proved that nearly all the goats on the island of Malta were infected and the organism was isolated from the goat's milk. Needless to say the disease is prevented by simply heating the milk.

Many of the infectious diseases may be prevented by other means than those referred to. Experience has taught us that often an individual who has had one attack of a disease is immune from a second attack. This fact was observed from the earliest times especially in relation to the plague at Athens and smallpox in China.

The very first example of practical application of this was noted in China at least 1100-1200 B. C. Here children were exposed to smallpox or actually inoculated with the serous exudate or dried lymph. It was hoped that the disease which ensued would be mild in form. They then usually survived and were rendered immune, that is refractory to the disease. There was no change in this method for 3,000 years. This variolation—to produce a mild form of the disease—was introduced into Europe by Lady Montague about 1720.

Another phase of this came up in 1795 when Jenner, who was trained by John Hunter, noticed the absence of smallpox among those having had cowpox. He mentioned it to Hunter whose famous reply was "don't talk, try". This led to our modern practice of vaccination against smallpox, a blessing with which we are all familiar.

This principle of protecting against disease (vaccination) was advanced by Pasteur almost a century later; a little over 40 years ago. It was discovered quite accidentally in 1880 by Pasteur and his assistants while they were working with the germ of chicken cholera. The experiments were set aside during the summer vacation after which the cultures were found to be markedly changed as to their disease-producing qualities.

Since cowpox, which is a modified or weakened (attenuated) form of smallpox, protects against the disease of smallpox, Pasteur reasoned that immunity to other diseases might be likewise brought about. Acting upon this assumption, Pasteur attempted to protect fowl against chicken cholera by first inoculating them with an attenuated specific culture. He was able not only to induce immunity against this diseases but later successfully vaccinated against other diseases such as anthrax, and swine erysipelas.

Pasteur discovered that the pathogenic properties of a parasite toward its natural host might also become changed by serial passage through other animals; by desiccation as well as by other means.

He utilized these two principles to protect man against the dreadfully fatal disease of rabies. This often is spoken of as the crowning achievement of his 30 years of constant work. By repeated passage (270) through the rabbit of the "street virus" type of the disease, which had a marked varying period of incubation, he was able to standardize the rabic virus so that it killed this animal uniformly in six to seven days. Immunity was produced by several injections of a suspension made of the spinal cord which had been previously attenuated by drying over caustic soda.

Soule, aware of the fact that in the early times in India and Africa, natives were protected against the ill effects of snake bites with small amounts of snake venom, in 1885 found that when susceptible animals were repeatedly injected with sub-lethal doses of the venom that an increased tolerance for the poison and a relative immunity was gradually built up. This was the first experimental evidence of such protection.

In the following year Smith and Salmon first demonstrated that dead cultures upon inoculation induced immunity also.

In the same year Roux and Chamberlain used dead cultures of symptomatic anthrax and obtained protection.

It was also found that in some cases equally good results ensued by injecting filtered culture fluids devoid of bacteria (filtrate).

In 1888 Roux, Yersin and Martin made a classical study of diphtheria. They showed the exact relation of the bacillus to the disease and demonstrated the existence of the soluble toxin. This work led directly to antitoxic immunity.

Kitasato and von Behring used tetanus and later diphtheria toxin to protect against the respective diseases. They further discovered that the blood serum of an animal actively immune against the diphtheria toxin would in turn protect (passively) other animals against fatal results. This is the basis of our present day antitoxic treatment which von Behring 1893 first introduced for human use. Roux, '94, used the horse to produce antitoxin on a large scale.

A practical application of determining the susceptibility of a person to diphtheria was made quite recently by Schick. In a susceptible person a local irritation ensues upon the injection of a small amount of diphtheria toxin. In the case of a positive Schick test the individual should be immunized either with antitoxin (passively) or with mixtures of harmless toxin-antitoxin (actively).

Innumerable attempts have been made to apply this means to protect against various other diseases. The anti-bacterial sera of which anti-meningococci of Flexner and anti-pneumonic which have proved to be helpful in certain types of these diseases are also available.

Recently Roux, the successor of Pasteur and at present director of the Pasteur Institute, Nicholle and Conseille have developed a sero-vaccination for protection against measles. The serum is drawn from the convalescent between the sixth and tenth day after the subsidence of the fever.

These scientists recommend, in view of the fact that the immunity lasts but a short time, that one day after the child receives the inoculation an injection of blood serum (infective) drawn from a person sick (fever) with measles be made. This confers not only a longer but a higher degree of immunity. It has been conservatively estimated that "tens of thousands" of children have been saved from measles by this procedure.

Haffkine, '92, in the Hamburg cholera epidemic, vaccinated with living spirilla attenuated by long culture and later introduced it into India on a large scale.

A few years later ('96), Kohle introduced prophylactic vaccination against cholera by using cultures killed by heat or by chemicals.

This work led Wright to try out a typhoid vaccine. It was quite unsuccessful in the Boer war and it was dropped in the British army. Then Leishman also of the British army took up the work. Soldiers were treated and men in the same company living under similar conditions were used as controls. The results were quite conclusive.

After our bitter experience in the Spanish-American war, our army board took up the matter. During the Texas manoevures in 1909 hardly a case of typhoid fever resulted and the treatment was extended to the entire army with marvelous results.

Today we can positively say that typhoid fever is a disease that need not exist and can be avoided by simply applying our knowledge of how it is transmitted (water and milk borne) and by vaccination.

The same treatment was applied by Shiga, '98, to dysentery with success.

Wright urged vaccines for all germs and as we know the idea has

been seized upon by manufacturers with their list of shotgun vaccines and bacterines.

Shortly after von Behring, '90, discovered that immune serum possessed antitoxic properties it was noted that it had other specific reactions which bear a very practical significance from the standpoint of clinical diagnosis.

In setting forth the reasons for the reactions of immune sera, it was conceived that various body fluids possessed anti-microbic properties or were anti-infectious due to cytolytic (cell dissolving) action. This was nicely illustrated by Pfeiffer's work in 1894. He showed that when virulent cholera germs are injected into cholera immune animals that the vibrio finally fell into granules and dissolved apparently "like sugar in water". This lytic or cytolytic action is spoken of as Pfeiffer's phenomenon.

This led directly to the demonstration that as a general proposition when any foreign protein is introduced into the animal body certain reactions are set up.

Among such immune bodies generated are agglutinins, precipitins and lysins. The phenomenon of agglutination, which is the clumping together of micro-organisms by a specific serum, was first noticed by Pfeiffer but no attention was paid to it.

Through the efforts of Widal, Gruber and Krause it was noted that its practical application was twofold: (1) the recognition of disease and (2) the identification of the organism. In the former case the serum of the suspected typhoid fever patient is brought in contact with a known typhoid fever bacillus and if the phenomenon (Widal test) occurs a positive diagnosis is made. While in the latter instance the blood serum is known to cause agglutination with a specific organism.

Precipitation is the combination of a soluble protein substance such as blood, serum, egg white, meat extract, bacterial filtrates, etc., and the corresponding immune serum, resulting in the formation of a flocculent precipitate. And thus it too can be used to identify disease and various soluble protein substances, such as may appear in blood stains. This may be important from a legal medical standpoint or in determining the source of meat as in the case of sausage suspected of containing horse or even dog flesh.

Lysis is the disintegration of organized cells (plant or animal) by specific immune serum. Bordet and Gengou first noticed this lytic action of immune serum. It was observed that it was comparable to gastric digestion in that there is a substance (immune body, sensitizer, amboceptor) which is not easily destroyed by heat (thermostable) and in that respect resembles the hydrochloric acid. Another substance (alexin, complement) is readily removed (thermo-labile, 56° C.) and is similar to the pepsin of the gastric fluid. The latter is present in all normal blood. When bacteria are thus dissolved it is referred to as bacteriolysis; when red blood cells are destroyed it is known as hemolysis, etc.

These reactions are specific. Consequently injections of red blood cells of human source or typhoid fever germs, etc., into animals produce the development of antibodies (lysins) which have the property of dissolving only the substance (antigen) which caused their appearance.

Thus the various red blood cells may be identified and one may positively say that this blood is or is not human in nature. Such findings have proven to be very valuable in fixing guilt in the case of murder.

The various other body cells and tissues, as of the spleen, liver, kidney, brain, placental as well as others, may be recognized by the application of this serological test.

Bordet and Gengou also found that when red blood or bacterial cells were treated with immune serum from which the complement had been removed by heating (56° C.), that they become susceptible (sensitized) to the action of the normal constituent in the blood (complement). And that if now these sensitized cells were added to fresh serum all the complement present in this serum would be taken up (fixed) by them so that the fluid no longer dissolved cells.

Thus the Bordet-Gengou phenomenon is also known as the complement-fixation test and is important in identifying diseases. It finds wide practical application in serology and when it is used to diagnose syphilis it is referred to as the Wassermann reaction.

The phenomena of agglutination, precipitation and lysis and their various modifications have a very great importance and practical significance in immunology and are used in the daily routine in all clinical and public health laboratories where they have become indispensable.

IDIOSYNCRASY.

In 1835, the effect of reinjection of protein substances was noted. In the early nineties this subject was again brought forth in serological work with tetanus and diphtheria.

In 1902 Richet, while studying poisons in sea animals, also observed this effect of reinjection of protein material. He proposed the name now used, anaphylaxis (without or no protection). Von Pirquet and Schick used the term allergie, meaning "off the normal". Hyper or supersensitiveness are different names for the same condition.

Arthur, '04, following up Richet's work on the suggestion of Chauvei used horse serum on rabbits and obtained the same results. Accumulative poisoning following repeated injection of protein is known as the Arthus phenomenon.

In 1904 and 1905 clinicians began to observe certain results following serum treatment, (tetaus and diphtheria antitoxin) e. g., restlessness and peripheral irritation perhaps skin eruption followed by paralysis, convulsions and even suffocation and death.

Von Pirquet and Schick collected a number of such reports into a book entitled—"Serum Diseases".

Theobald Smith, '05, called Ehrlich's attention to this strange phenomenon. Ehrlich turned this problem over to Otto who in 1906 published a paper on the Theobald Smith phenomenon.

About the same time Rosenau and Anderson, while working on the standardization of toxins and antitoxins, published a paper on the behavior of guinea-pigs to serum. Literally thousands of articles have since been published on this subject.

Summing up all the experimental evidence shows this to be a

specific protein phenomenon and occasioned by any protein whether plant or animal.

Along the line of such protein sensitization we have certain diagnostic applications.

Koch's tuberculin which is prepared from the tubercle bacillus or its products of growth, which are protein in chemical nature, reacts markedly when persons or animals affected with active and masked or incipient forms of the disease. The von Pirquet or cutaneous; the Calmette or ophthalmo; the Moro, percutaneous or ointment; the thermal and the Detre differential are tests of this type for tuberculosis.

Mallein which is prepared in much the same way as tuberculin is used in the diagnosis of glanders.

Similarly luetin, a filtered culture of the syphilis spirochaete, is used to test for syphilis and gives a local reaction in 24 hours in an individual afflicted with the disease.

Hay fever, in many cases, at least, seems to be a sensitization from certain vegetable proteins (pollens) followed by a reaction during the pollen season. The practicability and clinical value of pollen extracts in diagnosis, prophylactic and as a curative means is well known.

Idiosyncrasy or charactertistic symptoms of poisoning due to foods, such as eggs, fish, oysters, milk, cheese and cereals, among certain individuals may be explained along these same lines of hypersensitiveness or anaphylaxis.

Chemotherapy.

Just as the application of antitoxins and anti-infectious sera, vaccines, and the various tests used in clinical diagnosis are bacteriological problems, so is the combating of microbic disease by use of chemicals. We are here also concerned with the micro-organic cause of disease, its prevention and cure.

Before the days of bacteriology man had successfully combated only two diseases: malaria with quinine and syphilis with mercury. The laboratory has already accomplished wonders. Emetin, the active principle of ipecac, has been found to be specific for amoeba.

The injection of pure chemical substances into the body in curing disease was early thought of. Most everything under the sun was tried sooner or later. An example of this chemical work was the injection of sodium carbonate in an effort to so change the reaction of the body that the organism could not grow.

The discovery of anti-sera sidetracked this work but it was revived in a different spirit in 1900 when investigation of protozoal forms became important as pathogenic organisms. The "ultima thule" was Ehrlich's "Therapia sterilisans magana", that is, to kill everything at once—complete sterilization.

In the treatment of humans different conditions are involved and one cannot always use one large sure-cure dose. It, therefore, is most desirable and is the aim of this whole line of therapy to select a drug which has specific and parasitotropic properties (having greater affinity for the parasite than for the tissue of the host). It was noted that if a large enough dose cannot be injected so as to kill all the micro-

organisms at once, some forms, especially trypanosomes, can tolerate the chemical used (chemofast) until finally the drug has no effect whatsoever on the parasite. In such cases, however, the rotation of chemicals of a widely different chemical nature have proven beneficial.

Arsenic was first used quite empirically. Livingston, a missionary in South Africa in the early fifties, administered arsenic in the form of Fowler's solution (potassium arsenite) to his animals sick of tick fever. A temporary improvement was noted but this was soon followed by a decline and they finally died. Lingard used arsenic, again quite empirically in India, to combat surra, a trypanosomal disease (*Trypanosoma equium*) which attacks horses, elephants, etc., but with no marked results. There was usually death after temporary improvement.

In 1905 Thomas tried other arsenic compounds. He used atoxyl (sodium p-arsanilate), a proprietary arsenic compound, with fair results. Koch used atoxyl on humans and animals in Africa and again it was the same old story—a temporary improvement but eventually death.

Arsenic in the organic combinations of arsphenamine, commonly known as salversan or 606, and neo-arsphenamine are intensely destructive to spirochaetes in general and are universally used in combating the spirochaetes causing syphilis and yaws. They are specific for the spirochaetes, responsible for the relapsing fevers; are used in the treatment for trypanosomiasis and are beneficial in certain cases of malaria where quinine seems to make no headway.

Antimony compounds were also tried out and tartar emetic (potassium antimonyl tartrate) was especially successful when used with animals. But a suspension of fine electrolytic antimony injected intravenously is the best of all. Antimony seems good in cases of Leishmania of the skin and with Granuloma (venereal) it is marvelously effective, While in Framboesia (yaws), a disease resembling syphilis and also due to a spirochaete, very successful results are noted with the cutaneous type of the disease. It is a specific for filaria.

The active agents used in chemo-therapy are now narrowed down to arsenic and antimony and their compounds in treating blood parasites.

These are some of the many practical applications accomplished in bacteriology which, remindful of the fact that the subject as an exact science has been established less than one-half century, are indeed quite marvelous.

Incalcuable benefits ensue to mankind and his onward movement are made possible by the utilization of those micro-organisms which are useful and the destruction of those which are harmful either before or after they enter the body of man, lower animals and plants.

A PLEA AGAINST OVER-STANDARDIZATION IN SCIENTIFIC EDUCATION.

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We who spend our days in the study and application and teaching of science like to feel and believe in the absolute definiteness of things. Laws are thus and so. Changes of chemical or physical nature follow perfectly definite courses, which can be predicted if we are in possession of sufficient data and knowledge of premises. Principles of nature are immutable and it is our chief business to further the study and understanding of these principles, so that they may be utilized to the benefit, rather than neglected to the harm, of mankind.

This is quite right. And research, application and teaching constitute the trinity of activities necessary for carrying out this ideal program. To discover more of that which is now hidden; to flood with light that which is now dark; to turn mysteries into commonplaces; to bring man into that mastery of Nature's habits which is necessary to give us association with her on equal terms, rather than domination by her, that is the work and pleasure of the scientific researcher. To apply this mass of knowledge of what nature may do for us, in the concrete use and proper direction of natural law—such is the life work of him who devotes himself to applied science. And to put order and intelligibility into all of this, so that the neophyte may be interested and efficiently trained; to make clear the path for coming generations to follow, so that knowledge shall not die with its discoverer, such is the duty and the privilege of the teacher.

But if we thus attempt to classify and segregate these three groups of scientists, we shall soon find that neither this classification nor any other can be successfully supported.

What researcher of any effectiveness but has visions of his work bearing fruit in changed conditions of life or in increased comfort and lightened burdens of humanity, and desire and some ability in the communication of his discoveries to the world?

And what inventor or worker in applied science is there whose power of observation is not constantly yielding new food for thought, or who is not, in some degree, a teacher of his fellows?

And, finally, how can a teacher successfully impart inspiration and scientific knowledge to youth in the school and colleges and universities, if he has nothing to do with some activity in uncovering the as yet unperceived truths of his science, or if he has not some desire, fulfilled directly or indirectly, even though always imperfectly, to apply these truths? He is, as Charles Dickens says of the guide-post, always pointing the way, but never going there, thus, perhaps, a very successful guide-post, for those who have occasion to make inquiry, but a very indifferent teacher.

We have thus the paradox of a science which is all order and rigid system, in the service of which are men whose mentalities and modes of thought and work are not subject to order or systematic classification

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according to any known rules. Were it not so, life would be a very drab affair. When the time comes (if it has to come) that character and personality, knowledge and enthusiasm are to be blocked out with compass and ruler, when reflection and reason and mental creativeness can be run through the "qualitative scheme" and labeled with all of the appropriate prefixes and suffixes and according to approved standardized spelling, we shall then be living in a colorless and tasteless and odorless world, to be sure.

Not only is it not possible to standardize human life and endeavor, it is an absolutely unthinkable proposition. But we are constantly trying to do this with our educational system, which has so much to do with the shaping of life. The very word "system" implies as much. We must agree upon methods of teaching. We must agree upon text books, if possible, and all use the standard system of books. We should standardize the length and content of our courses, the number of hours to be spent in administering them and, by the student, in studying them, the kind of preliminary examinations to be administered to candidates for education, the principles to be used in grading examination papers, the number of "experiments" or "unknowns" or "subjects" to be required of the student, and the number of years that the work of this system shall be followed (pursued or taken, according to the point of view), and so on and so forth.

Whether the lecture system is a failure or is not a failure—that is a question that has long been debated. We should like very much to know, so that we could definitely adopt it or rule it out, for our standard courses in science. I should say that the lecture system is a failure, and that it is not a failure, just as will be the case as long as it is used, and just as will be the case with every other system that ever will be tried. It is a failure in one class because the professor's conception of a lecture is to exhibit to his students the dry-bones of science in all of their inhuman nakedness, and without a particle of living flesh to cover them. Or else he recounts, with infinite pains and with absolute fidelity, the lessons exactly as they are found in some text book or in his notes. In which case his class room becomes the abiding place of boredom.

The system is a success in another class because this professor is able to remember when he, himself, was a student. He knows that his students are unlikely to learn much from the spoken lecture unless they first become interested and that one is not easily interested in anything that is presented only in its ugliest and most uninteresting aspect. He is able to lead his students to think, and to generate in them the will to extend their study outside the class room, while the other can teach effectively only by hearing required recitations on assigned lessons.

I think that the most naive argument for standardization of chemical education that I have heard is this: that it is highly desirable that when a student goes from one college to another, or from a college to a university, he shall be able to "make connection" with the least possible loss of time or effort. "Chemistry," "taxonomy," "optics" and other such names shall mean, then, just the same thing in one place as in

another, in high-brow East or uncouth West, in "liberal arts" or "technical" college.

A certain amount of standardization is, of course, necessary and desirable. We must utilize the current conception of "clock hours" and the same conventional calendar of days, months, semesters and years (astronomical movements knowing no favorites), from which naturally follow "semester hours", "credits", "courses" and "graduation", also even "degrees". This is not objectionable, it is necessary and desirable, as I have just said. We should have some sort of definite notion of what four years of college work and any specified number of years of university work is to mean, in the matter of opportunities. But there is no sort of possibility of measuring the *results* of these opportunities by saying that the student has "had" or "taken" or "pursued" certain named courses or has received certain named degrees, unless you further specify where and how the opportunities were found. Not "where" in the geographical sense, nor with reference to the name of the school or the character of its traditions or the prowess of its football teams, but in the sense of the character and ability and enthusiasm of its teachers. The age of the school, the style of its architecture, the wealth of material equipment mean nothing, or so nearly nothing that they may be ignored, unless the men and women who constitute the soul of the institution in the form of its teaching staff are those who carry their students irresistibly into the swing of their own enthusiasms, so that the hard work which is involved in education and scientific training becomes recognized as a rare opportunity and a real pleasure.

Let me say here, with as much appearance of boldness as possible, that I do not want to standardize college teaching very far beyond elementary mechanical particulars; largely because it cannot be done. Let us suppose that two men are giving instruction to their respective classes in the same building. Let the classes be so assorted that their general characteristics are well balanced in the two divisions. Let the professors teach the same lesson, using the same text book and (let me carry the illustration to the extreme of absurdity) even saying the same words.

What is the result? One group of boys comes from the room at the end of the period, enthused, wideawake, refreshed from the hour's experience, with the consciousness of some new step taken in the delightful progress toward scientific understanding and with pleasurable anticipation for the next day's work. The other group comes out soured, disgruntled, pessimistic toward the whole question of education, and cynical and rebellious toward the arbitrary requirements of the college. What is the reason? Nothing any more difficult to understand than this: that different men were doing the teaching. The students absorbed what was about them. They caught the contagion that was in the air.

Have I not mentioned what we all know to be a perfectly familiar state of affairs and need I elaborate upon this topic? I shall do so only to the extent of saying that the unsuccessful teacher may have been intentionally following an absolutely correct and approved system

of teaching, while the other may or may not have been conscious that he was following any system. The difference was in the men themselves and this difference must always exist. I am not saying that the poor teacher should not study to improve, not his method or system, but his *results*. But that must be done by an entirely different process. It may even not be done at all, in which case this man should give up teaching and seek to acquire wealth in some other way.

What we must recognize is that there is a certain intangible something that makes men different from each other, that gives some the ability to do well that which others may do only poorly or not at all, and that this difference is nowhere more striking than in the world of the teacher. When we contemplate the numbers of individuals who have found their way into the ranks of college (nay, and of university) faculties, who have no ability whatsoever for teaching, who never can have any ability, and who are without vision or inspiration, even if we assume (as we may if we have sufficient optimism) that the lazy and indifferent teachers are usually weeded out—even then, what a sight it is and what a thought it is that so many young men and women have to lose the only opportunity for an education that they ever will have, simply because they chose the wrong college, or the wrong course in the right college, or the wrong class and the wrong teacher in the right course in the right college.

There should not be any such thing as a wrong and right college, course or teacher, except as this may be understood to refer to the innate fitness or unfitness of a student for a given kind of work. Certainly it should not be that the purposes of scientific (or other) education should be thwarted by having our science faculties poisoned by the presence of incompetent or uninspired teachers. But this does not point to standardization. It points in exactly the opposite direction. It means that the state of affairs should be such that no matter where the student goes, whether from intelligent choice or from fancy or necessity, he shall be placed under the guidance and oversight of men and women who know their subjects, who believe in their work and whose whole efforts are in the furtherance of interest in and understanding of the kind of knowledge which they are charged with teaching, *but each of whom gives to his students something that he alone can give.*

When this shall be so, every student (if he be a real student) will find a great opportunity, no matter what college or university he may choose and no matter what particular teacher may come to him as his drawing in the lottery of college "assignments". His opportunity will be different from that of another student who has gone to another school or who has drawn another teacher, but so it should be.

Have you ever considered what it is that makes the meetings of our scientific societies such a rare pleasure to all of us? Is it not the contact of mind with other minds and of character with other character? Is it not the exhilaration which is the product of the reaction upon our own mental habits of the mental habits of others whose interests are similar to ours but whose ways are different? And when we gather at our alumni dinners do we not dwell, more than upon any other topic, upon the special characteristics of the various teachers under whom we

have sat in the past? Imagine! Would it not be a pleasant occasion if each of those teachers had taught the same things in the same way as did all other teachers of like subjects, so that one might drift from one class to another "without losing any time in the process"? And would our society meetings not be charming little affairs if we had all been turned out of such a perfect system so that, mentally speaking, we should be like the little cast-iron kewpies that our engineering college foundry makes by the thousands to give to visitors as souvenirs?

A committee of the American Institute of Chemical Engineers has recently made a comprehensive survey of the curricula of a large number of American colleges who give work in chemical engineering. The results are extremely interesting and there is no doubt that they will be useful, as well, to those who are charged with the planning of such curricula. It is well that we should exchange ideas to the greatest possible extent, to the end that human experience shall be utilized in this, as in other tasks of similar nature.

One thing that is shown very strikingly is that nobody seems to know very definitely just what a "chemical engineer" really is and that nobody appears to have arrived at a very convincing definition of what should be called "chemical engineering", at least so far as this term applies to curricula leading to a specified degree. Such conceptions appear to range all the way from engineering with a smattering of chemistry to chemistry with a smattering of engineering, and from a supreme emphasis upon scientific fundamentals to a like emphasis upon plant practice, with every intermediate degree of opinion represented.

After all, why should this condition of affairs not be a reasonable expectation? To the extent that these differences in emphasis result from different grades of teaching success in the various departments, they are natural and inevitable. They are even desirable, if not overdone. In one institution, let us say, is a commanding figure at the head of the faculty of physics. He is not only a well trained scientist, able to give authoritative information along the lines of his own specialty, but he is likewise a man of splendid idealism and of outstanding ability as a teacher, eminently successful in his contact with students. He is familiar with the value of his science as applied to the industries and he is apt and energetic in acquainting his students with the principles of such applications. His colleagues will, very likely, be inspired with his spirit and his department will be inclined to develop, in personnel and in methods of work, to outstanding eminence. This department will then be known, on and off the campus, as a very desirable and profitable place to study.

In the same hypothetical institution the work of certain other departments may be of mediocre character, not because of the lack of that much to be desired "material equipment" but because of the lack of human qualities necessary for building really meritorious courses of instruction. As to the divisions of work within the departments, the situation may be similar to that which we have imagined as between departments.

The natural result, in this hypothetical institution, is a general leaning toward the kind of work administered in the department or the division which is dominated by the spirit and enthusiasm and ability of these hypothetical professors. At least this *should* be the natural result and it will be if the general oversight of the institution and of its curricula is in the hands of men of broad vision and purpose, whose planning goes beyond the ideas of credits, hours and standard courses, to ultimate effects upon the training of students for useful and happy lives in the scientific industries and research laboratories. Unfortunately this is not always the case. The crime of visiting petty annoyances upon this or that too successful teacher and of undermining his work in order to attain the impossible result of magnifying the work of another by comparison, or of withholding support from this or that too successful department, is still being perpetrated, to a greater or less extent, in most of our colleges. And what a tragedy of wasted years and means, and of baffled and disappointed youthful ambition it is, that so many of our young men, through no fault of their own (unless ignorance of the fate that awaits them may be considered a fault) find themselves in colleges and courses and classes where the best that they are likely ever to acquire is a precocious cynicism, a pessimistic philosophy whose cardinal principle is to "get by" the professor, the college and the world.

Is it any wonder that a student, thus disillusioned, turns with relief to the hectic pleasures of the jazz parlors or to the gladiatorial combat of the football field, or that he sometimes applies this same cynical philosophy to the latter enterprise? Here, at least, energy and enthusiasm find an outlet in endeavor that has a chance to win some sort of reward and approval. Perspiration and mental struggle may even earn the satisfaction of public applause, whereas in such classrooms as these there is no satisfaction or sense of accomplishment, other than that represented by certain marks in the professor's class book and on the cards of the Registrar.

If we should now go to another college we should find a similar state of affairs, with the exception that the emphasis might here be in some other direction, which would again depend upon the characteristics of the individuals of the department faculties within that school. All of these differences in emphasis would show very strikingly in a chart of hours devoted to typical subjects within the curriculum.

These are merely two illustrations, selected entirely at random and of purely hypothetical character. Let us extend the list and we shall have a situation, not merely common but almost universal, of colleges in which the work of the various curricula and departments, and of the various divisions within the departments, is not well balanced, or does not appear to be well balanced, simply because of innate differences in the minds of men. Where this lack of balance is the result of conditions such as I have outlined, it is a very grave mistake to attempt to correct it by subtracting from the work or influence of apparently over-emphasized departments, or of successful individual teachers within these departments. The inevitable result is a destruction of whatever merit the curriculum might originally have possessed. Such correction must begin with a real upbuilding of the deficient depart-

ments or courses, not simply by throwing increased financial support to their material equipment but by improvement in personnel. This (if my observation is a reliable indicator) is one of the most perplexing problems of college management. Too many presidents and deans apparently lack the courage to get rid of incompetent and mischievous teachers, especially when the latter form a part of an internal political system that is hard to break. But it is the only real solution.

If, then, it were possible to standardize scientific education to the *n*th degree, if it were possible (as it never will be) for us to come to unanimous agreement as to length, content and sequence of courses, upon method of presentation, upon text books and examinations and grading and degrees, we should be very little nearer a statement of what effective training in science should be. For we should still have, as I hope we always shall have, those personal differences in the characteristics of the teachers of all of our colleges which break up, in such a human and delightful manner, the mechanical routine of study and class work and which give, or should give, every alumnus of every college some ground for boasting of the excellence of his own alma mater. And upon these differences, to a very considerable degree, must be based the practical distribution of work in a given curriculum.

As individuals and as faculties we believe in and fight for academic freedom. And that is right. Let us understand that this idea shall include the freedom to throw our individual selves into our teaching and the assurance that our tenure and the moral and material support we receive shall not depend upon any views upon political, religious, economic or ethical questions we may hold and express, so long as these are sincere, or upon personal favor of any kind, but upon the results of our teaching, viewed in the broadest possible way.

In this paper and elsewhere I have repeatedly dwelt upon the importance of good teaching. I believe that the mechanics of courses and curricula, of quizzes and examinations, of honors and degrees, are of very vital importance and it is necessary that they should be worked out in the most intelligent manner possible, to the end that some degree of uniformity should attend our various and united efforts to train our young men and women for careers in the work of science. But machinery, however perfect, will not run itself. You may have a mammoth educational plant, an all but ideal equipment of machinery and apparatus and materials, and your courses and curricula may be planned with the utmost skill, but if the soul of the institution is non-existent there will be no education that is worth a fragment of the cost. As I have already indicated, the soul of the college, of the university, is its teaching staff and no amount of mechanical standardization is going to develop a soul. Not only this but too much standardization will inevitably cramp and destroy such a soul. A teacher must, of necessity, be well prepared in the subject which he undertakes to teach but he must also be a born teacher, loving his work, feeling its importance and taking infinite pleasure in observing its effects upon the scientific ideas and ideals developing in the minds of his students. And he must have originality and spontaneity. Otherwise he is a foreordained failure.

This plea, then, is not against standardization but against over-emphasis upon standardization. I am not arguing for chaos in scientific education. But I do plead for the highest possible degree of individualism in teaching. The relations between student and professor are not susceptible to any sort of standardization. The appeal of mind to mind must be a matter for individual development and the question of just what is to be taught, and how, cannot be decided wholly upon the basis of teaching system, or of clock-hours, credits, courses or semesters.

We must not make a fetish of system. Why, I have heard members of a college faculty argue with energy, and even passion, for insistence upon the minutest details of their courses as they had developed them. One might suppose that the routine of their semester's work had somehow come down from Sinai, along with the thou-shalt-nots, or that "eighteen-weeks-three-times-per-week" were one of the established laws of nature.

Our problem must include a solution of personal equation. It might easily be that the two extremes of opinion, as represented in the educational survey to which I have already referred, will turn out graduates about equally useful and equally qualified to represent that somewhat nebulous individual, the "chemical engineer", if these extremes of development have followed as a natural consequence of the presence of conspicuous ability in the departments represented by these extremes. It is too much to suppose that this is always the case. We should indeed be living in an educational Utopia if it were the case. But to just the extent that such apparently one-sided development is due to the policy of rewarding conspicuous teaching success by increased teaching opportunities, and not to the operation of "pull" or personal favor or politics, to such an extent will our scientific education be rewarded by outstanding achievement on the part of our teachers and of our graduates. When this shall be the case we shall forget much of our worries about standardization.

GEOGRAPHIC VARIATIONS IN INDIANA IN TYPHOID, TUBERCULOSIS, CANCER AND IN TOTAL DEATHS.

STEPHEN SARGENT VISHER, Indiana University.

For some time the writer has been interested in the geography of Indiana, and in the contrasts among the different parts of the state. In the *Proceedings* for 1922, may be found a paper dealing with some contrasts, and in a book recently published, more than a hundred maps are given showing the contrasts in the production of crops, in the climate, mineral resources, etc.

The contrasts among the counties in the death rates given by the State Board of Health each year in the Yearbook of Indiana afford additional illustrations that there is considerable diversity in even so small and homogeneous a state as Indiana.

As the rates are small in proportion to the population, and as epidemics and differences in the weather cause irregularities from year to year, the following maps are based on the average death rates for four or five years.

The four special maps, figures 1, 5, 9 and 11, reveal conspicuous contrasts among Indiana counties in death rates from typhoid, tuberculosis, cancer and from all causes. These contrasts may be explained in part by differences in geographic environment. Conditions that appear to help explain the differences in death rates are shown in the other maps of this paper. Figures 3 and 6 (as well as 1, 5, 9 and 11) have not been published before. The other five maps are from The Economic Geography of Indiana, Appletons, New York, 1923.

Typhoid Fever.—Indiana has a rather bad record for typhoid, having an average mortality of 12.8, which is 25 per cent higher than the average for the registration area of the United States. Furthermore the rate has fallen less in Indiana in recent years than it has in the nation as a whole. Figure 1 shows that several counties, those in black, have on the average, five times the death rate as do other counties, those in white. In the crossed counties, there is three times the typhoid risk present in the white counties.

According to these data, Lake County with its extensive marshy tracts and largely emigrant population, has the greatest average mortality from typhoid, an average of 35 deaths per year per 100,000 population. Four counties in the limestone area, shown in figure 2, have rates between 25 and 27.5. The other counties in this limestone region also suffer heavily, the disease apparently being comparatively easily spread through the agency of the poorly filtered ground water. It will be recalled that in limestone regions, water commonly enters the ground through sink holes and moves quickly along crevices, emerging perhaps miles distant, but not purified by filtration nor by spending a long period beneath the ground.

Other counties having a high death rate from typhoid are those in the coal mining region (figure 3) where many miners live without proper sanitary arrangements and without safe water supplies.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

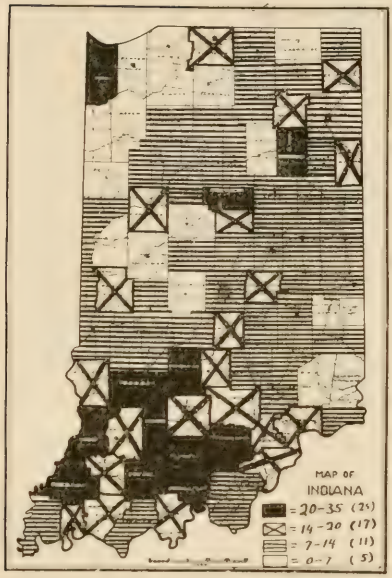

Fig. 1. Death rate from typhoid, the average of the four years 1917-1920. Data from State Board of Health reports.

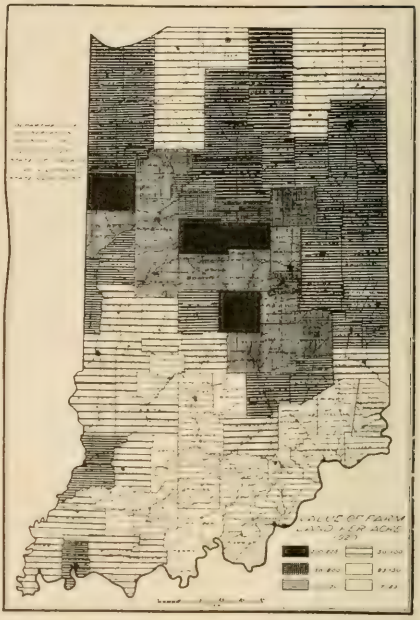

Fig. 4. Value of farm land per acre, according to counties.

Fig. 2. Section shaded indicating the area where limestone outcrops extensively and where the water supplies come from limestone.

Fig. 3. Section shaded to indicate the important coal mining area.

Some of the other counties with high death rates for typhoid are those in which the land is mostly rugged, the soil poor, and the people poverty-stricken. Figures 4, 7 and 8 illustrate the contrasts among the counties in respect to value of farm land, in per cent of waste land, and in the taxables per average square mile. Comparison of these three maps with figure 1 reveals several correspondences, many of the poorer counties having abnormally high death rates, while several of the richer counties are white on figure 1.

The unsatisfactory sanitary conditions characteristic of camp life on the shores of some of the lakes of the northeastern part of the state

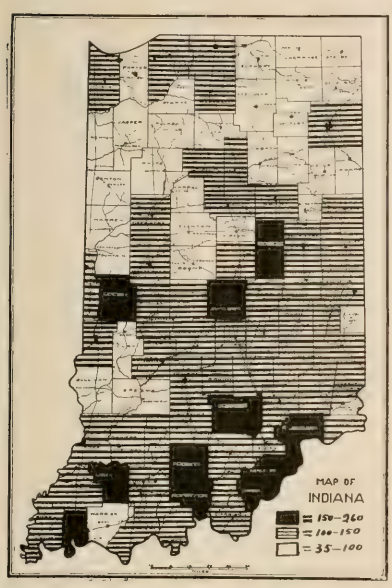

Fig. 5. Death rate from all forms of tuberculosis. Average of the five-year period, 1917-21.

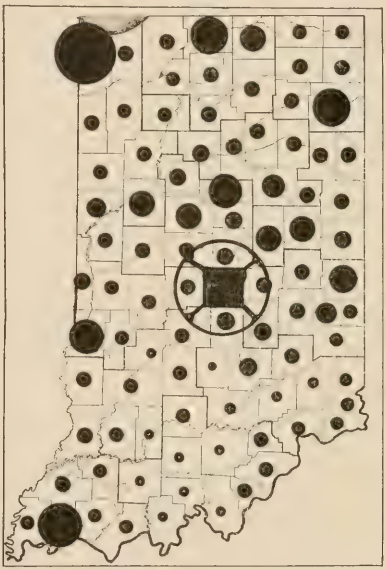

Fig. 7. Variation in taxable property per square mile in 1921. Values are proportional to the size of the circles, from less than $15,000 to $800,000 per square mile, by counties.

may help explain the rather high rates in some of the northeastern counties.

None of the counties having large cities are black in figure 1, except Lake County, with Gary. The larger cities of Indiana have provided a reasonably safe water supply, which is by no means true of many of the smaller towns and villages.

Tuberculosis.—The death rate from all forms of tuberculosis is nearly ten times as great in Indiana on the average as is the death rate from typhoid. The rate in Indiana moreover is about 25 per cent less than the average rate for the registration area of the United States. Figure 5, which is based on the average of the five years, 1917-1921, shows that there is less average contrast among the counties in deaths

from tuberculosis than in deaths from typhoid. Nevertheless the black counties of figure 5 have over three times the mortality in proportion to population as have the white counties. The two highest counties (Jefferson 261, Parke 246) have 5.7 times the average rate of two other counties (Benton 35.4, Lagrange 54).

Tuberculosis is spread by direct contact, and reflects low resistance, ignorance and lack of proper food and health habits. Figure 5 reveals a conspicuous contrast between the southeastern half of the state and the northwestern half. An adequate explanation of this contrast is not available, but figures 6, 7, 8 and 10 are interesting in this connection. Figure 6 shows the four counties having most negroes, and

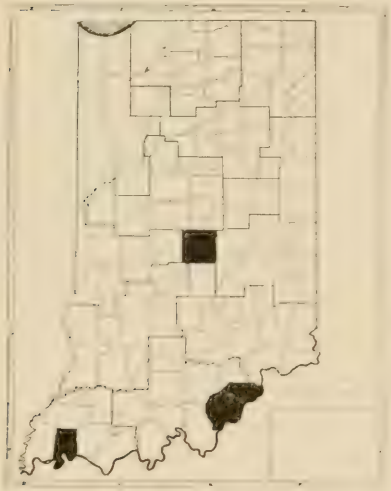

Fig. 6. The negro population of four counties exceeds six per cent (Floyd 6, Vanderburgh 7, Marion 9, Clark 9).

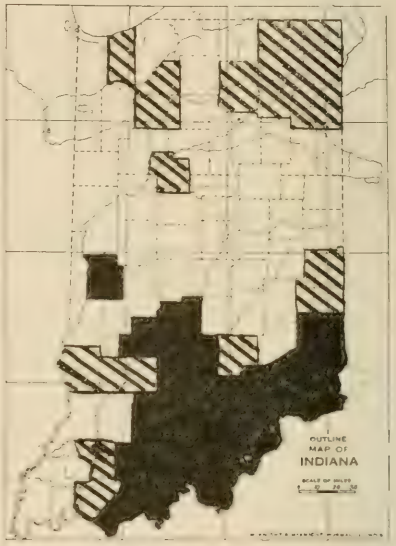

Fig. 8. Relative areas of waste land according to counties, as reported by the county assessors. Crossed counties 1/8 to 1/12 waste, white counties less, black counties more.

are the only counties in which the negroes make up as many as three per cent of the population, excepting Lake County which had 4.5 per cent in 1920. Each of these counties has a high death rate, partly because negroes suffer severely from tuberculosis. Figures 7 and 8 reflect contrasts in poverty, poor diet and low resistance. Figure 10, showing the change in population in the thirty years, 1890 to 1920, shows some similarity to figure 5. The counties that have lost population or stood still are largely in the southern section of the state, where tuberculosis is reported as especially prevalent. None of the large cities however have a low death rate from tuberculosis, perhaps because of their large negro populations, their congestion, their dust and their soot, for all of these increase the death rate from tuberculosis.

Certain special conditions doubtless help explain the peculiarities of figure 5. For example, Parke County is black partly because of its large tuberculosis hospital, in which many patients from other counties and states die. Another special condition has been suggested, namely that the doctors in the poorer counties of the southern part of the state are older on the average than those in the more industrial and richer central and northern counties, and are therefore more likely, physicians say, to report deaths from ill-defined causes as due to tuberculosis than the younger doctors.

It may be that figure 5 is partly explained by the fact that the southeastern half of the state is largely peopled by the descendants of

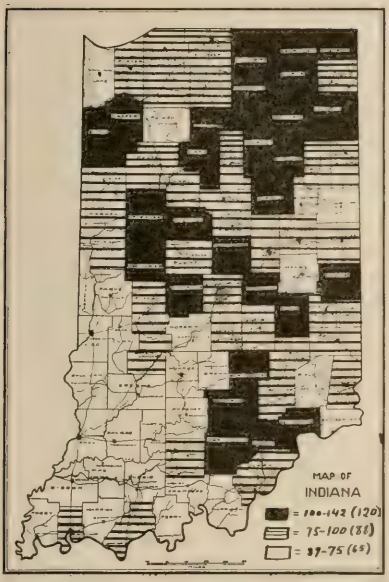

Fig. 9. Death rate from cancer per 100,000 population, for the years 1917-20. Data from the reports of the State Board of Health.

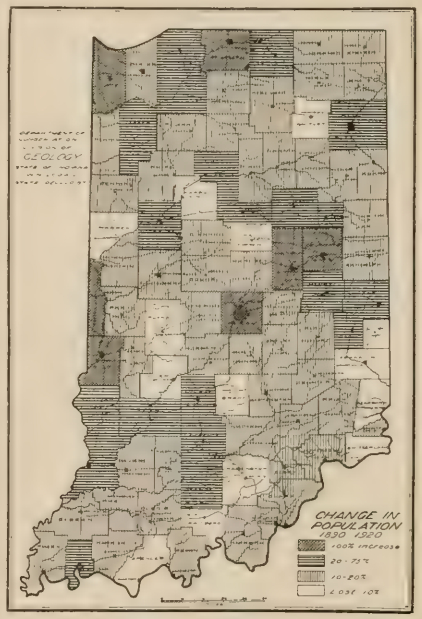

Fig. 10. Changes in population between the census of 1890 and 1920.

persons who came from Kentucky, Virginia, Carolina and Pennsylvania while the remainder of the state was originally largely settled by persons from New York, Ohio, New England and by recent immigrants from northwestern Europe. In the former case, the settlers moved into a somewhat more severe climate, while in the latter case they moved into a milder climate, with more sunshine, and where better dietary conditions prevailed.

Cancer.—The cancer map (figure 9) shows less regional contrast than prevails in typhoid or tuberculosis, the white counties having an average mortality of 65 and the black 120. Geographic influences are not clearly shown on this map, and some of its features are hard to

explain, for example, the fact that the mortality from cancer is relatively low in all of the southwestern part of the state. Most of the black counties, except in the south, contain considerable industrial populations (see figure 12). Some think that the exciting lives and rich diets in our busy cities tend to increase cancer. The high mortality in some of the southern counties may be due to the fact that most of the young people have left, leaving the older folks, the danger from cancer increasing with age. Figure 10, showing the change in population between 1890 and 1920, is interesting in this connection. Comparisons of figures 9 and 10 show, for example, that several of the counties which have increased most rapidly in population have a low cancer rate,

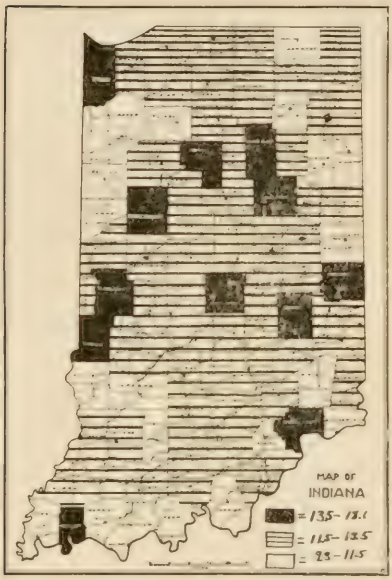

Fig. 11. Average death rate per 1,000 persons in the five-year period 1917-21, according to reports of the State Board of Health.

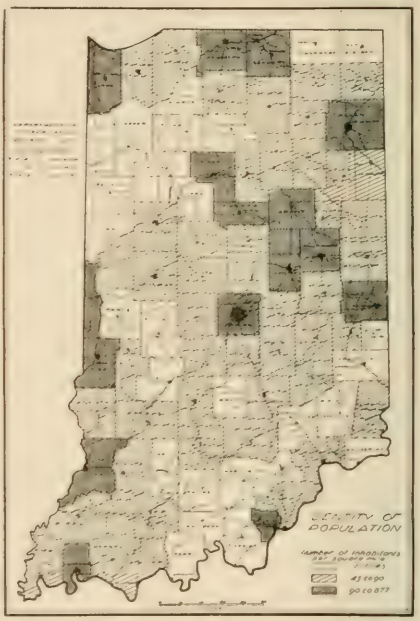

Fig. 12. Density of population in 1920, by counties.

presumably partly because few of their people have reached the age when cancer is especially prevalent. The low death rate from cancer in the coal mining counties of the southwestern part of the state may be partly explained by the demand there for workers in their prime. Other white counties in the southern part of the state may have a low reported death rate from cancer because the cause of the death of many of the poorer residents of the rougher counties may not be accurately diagnosed.

General Death Rate.—Figure 11 shows the average death rate from all causes for the five years, 1917-1921. It shows the least contrast of this series of death rate maps. The black counties have an average

rate of only about 50 per cent more deaths than the white counties. However, Jefferson County has over twice the rate of Benton and Adams counties.

The larger cities make themselves evident on this map, most of them causing their counties to be blackened. The average death rate from all causes, including accidents, in Indianapolis is more than 50 per cent more than the average for the state. Part of this, however, is due to the fact that many residents of the country and small villages die in city hospitals. Yet they are reported for the city in which they die. This defect in our law helps explain why Parke County, with its large tuberculosis hospital and several other counties with large hospitals have an abnormally high death rate.

The low death rate from some of the poorest counties in the state may be partly due to the fact that they have lost many of their young married people, those having children. The death rate among infants is of course far higher than is the rate among adults. The decrease in child bearing in rural districts, in spite of occasional large families, is indicated by statistics given in the Yearbook for 1922, which reveal that both the death rate and the birth rate in rural districts is lower than in cities. But the ratio of births to deaths is about the same, about twice as many births as deaths.

Comparison of figure 11 with the other maps may be made with interest. For example, figures 10 and 11 show that of the 21 white counties of figure 11, six lost population between 1890 and 1920, 12 remained about stationary and only 3 made appreciable gains. Most of the counties that doubled in population between 1890 and 1920 have high death rates.

Many other comparisons might be drawn, but space and time prohibit. It is hoped, however, that this study of the distribution of diseases and deaths in Indiana will be carried further, with advantage to those who follow us.

A CHANGE OF DRAINAGE OF RACCOON CREEK, PARKE COUNTY, INDIANA.[1]

GLENN G. BARTLE, Manteno, Illinois.

The area to be discussed includes most of Parke County, Indiana, and the northern tier of townships of Vigo County, Indiana. The villages of Rockville, Rosedale, Montezuma and Mecca are within the drainage area and the city of Terre Haute is only 10 miles south of the southern boundary.

Geologically, this area is in the region of Pennsylvanian Age, within the borders of the Illinois Glacial Invasion, and crossed by the Wisconsin Drift Sheet.

From the viewpoint of physiography, the region has been placed by Fenneman[2] in the Central Lowland Province of the United States and in the Till Plains Section. According to the more detailed physiographic divisions outlined by Malott[3] this territory includes parts of three separate divisions. The northern half of the district—that covered by the Wisconsin Drift Sheet—is a part of the Tipton Till Plain. The extreme southwestern part of the district forms the northern tip of the Crawford Upland, the region of the Mansfield Sandstone outcrop. Finally, the southern and western part is in the Wabash Lowland.

Topography.—In topographical forms the Tipton Till Plain, characteristic of central Indiana, is beginning to lose its usual appearance here, because of the nearness to the Wabash and its major tributaries. However, the Plain stands out flat and plateau-like between the stream valleys, and the northern part of this region usually gives the appearance of a rolling-plain prairie, lying from 600 to 650 feet above sea level.

The Wabash River and Raccoon Creek have a number of terraces. These terraces are not usually wide but some very productive farms are located upon them. Their elevation varies from 540 to 560 feet.

The Wabash River is about 450 feet in elevation at low water level. Its valley is higher, of course, and very wide in many places. Raccoon Creek cuts through to about 480 feet at Mecca.

Thus we have three rather distinct levels in the region: the prairie level, the terrace level and the flood plain.

Geologic Problems.—There are several geologic problems of interest in this region. I will merely mention a few of them in passing, leaving full discussion for one problem only.

An interesting structural irregularity is found near Coxville, known as the Coxville Channel or Coxville Carboniferous River. This 80-foot

[1] Taken from the author's treatise "A Geologic and Physiographic Study of the Region in the Vicinity of Raccoon Creek and the Wabash River, lying principally in Parke County, Indiana", being a thesis presented to the Department of Geology, Indiana University, as a partial fulfillment of the requirements for the degree of Master of Arts.

[2] Fenneman, N. M., "The Physiographic Divisions of the United States", Annals Assoc. Amer. Geog., Vol. 6, 1917, pp. 19-98.

[3] Malott, C. A., "The Physiography of Indiana", Handbook of Indiana Geology, pp. 66-94.

thickness of sandstone has been frequently mentioned by Ashley[4] and others, with the idea that it represents a region of embayment and filling in of Post-Allegheny sandstone—probably Merom—in the Coal III horizon. Logan, however, assisted by the writer and others, traced smut bands corresponding in elevation to Coal III and IIIa across the entire surface of the cliff. This would indicate, of course, merely an area of non-deposition of Coal III.

A careful study of the maps in the illustrations will show an irregularity in the South Prong of Little Raccoon Creek in the extreme northeastern part of this district. My data would indicate that in preglacial times this small stream drained directly into Troutman's Branch and thence into Big Raccoon Creek. More well drillings are necessary, however, to establish this absolutely.

The middle course of Big Raccoon Creek is blocked by a very definite butte near Mansfield, forming a cul-de-sac which has been studied and described by Dryer.[5] The indications here are that the Raccoon was a large tributary of the Wabash in preglacial times—"comparable only to the present day White River".

These problems are interesting and worth further attention, but cannot be discussed more fully here. The most important physiographic problem of the region may be briefly stated as follows:

Why does Raccoon Creek, flowing normally in a southwesterly direction (until it is within 12 miles of the Wabash), forsake its wide valley, which continues to the Wabash, and flow north for ten miles through a narrow valley which has been carved in bed rock?

We will attempt to answer this question.

Lower Raccoon Creek.—In its lower course Raccoon Creek flows through the shales and sandstones of the coal measures. From Mansfield it flows in a general southwesterly direction to the range line. The valley is regular—averaging about one-half a mile wide with bluffs 60 to 80 feet high. Just south of Bridgeton the valley widens and there is a pronounced terrace sloping gently from the bluffs to the valley level but very flat nearest the stream. It averages about 540 feet elevation—20 feet above the flood plain. The stream below Bridgeton has many meanders and is constantly changing its course. This was especially true this spring (1922) after the heavy rains.

South of the range line the valley continues to widen to a width of two or three miles and merges with the valley of the Wabash just south of Atherton. In this lower course the prairie level is reduced and the valley sides are cut down to a much smoother slope. The divide between Raccoon Creek and Otter Creek below Rosedale is composed of wind driven sand. There are a great many dunes stretching across the valley in sections 9 and 16 of T 13 N, R 8 W. These dunes are only 15 to 20 feet high but are persistent throughout the valley. All along the valley there is a great abundance of sand and the merging of the Raccoon and the Wabash valleys gives an excellent opportunity for action by the west and southwest winds.

[4] Ashley, G. H., "The Coal Deposits of Indiana", Ind. Dept. Geol., 23d Ann. Rept., 1898, p. 300.

[5] Dryer, C. R., "Wabash Studies", Ind. Acad. Sci., 1921, pp. 199-212.

Just east of Rosedale in section 26, T 14 N, R 8 W, there is an unusual amount of peat and bog, indicating recent laking. In the memory of people now living this region has been constantly covered with several inches of water.

Between this sand dune divide and the turn in Raccoon Creek the land is very flat and sandy. There are some artificial drainage ditches dug through the region by the land owners. The largest one of these, the Cox Dredge Ditch, follows, in my opinion, the ancient channel of Raccoon Creek. It starts at the C. and E. I. R. R. tracks in section 2, T 13 N, R 8 W, and flows southwest for about five miles into a small branch of Otter Creek. It has not been a successful business venture because the sand dunes have repeatedly clogged it and it has been subject to excessive filling in the spring. After passing the divide indicated, however, its grade increases and it becomes a fair-sized stream at its entrance into Otter Creek.

Raccoon Creek, as I have indicated, does not follow the valley but turns west in section 28, T 14 N, R 7 W, and, after a slight jog to the south near the range line, turns abruptly north in section 36, T 14 N, R 8 W—one mile east of Rosedale. From this point it flows northwest for about ten miles, through Coxville, Mecca and Armiesburg, and then west into the Wabash one mile south of Montezuma. It is joined in section 23, T 14 N, R 8 W, by Little Raccoon, in section 16 by Iron's Creek and in section 7, T 15 N, R 8 W, near Armiesburg, by Leatherwood Creek—all coming from the northeast.

Between Coxville and Armiesburg the valley varies from one-fourth to three-fourths of a mile wide. There is some outcropping along the hillside and a few bank coal mines on the west side. The valley is regular except that there are two definite terraces—one on the west side on which the village of Mecca stands and another on the east side just north of Mecca. These terraces are about 25 feet above the valley floor and are each approximately one mile long. The narrowest part of the valley is above Mecca in section 17. Another very narrow place is just below Coxville in section 22. Either of these places might have been saddles, or low places in the divide, over which the drainage was drawn. The gap in the Wabash bluff through which the Raccoon-Leatherwood stream passes is over a mile wide and is blocked by the Montezuma terrace. Raccoon valley, however, before it meets Leatherwood, is only a quarter of a mile wide. The cut through the terrace at Armiesburg is only about 750 feet wide.

Clearly, the Raccoon once flowed directly southwest into the Wabash below the south tip of Atherton Island. Just what caused the deflection can probably never be fully determined. I will give several theories in brief.

Dryer[6] believes that there was once—probably in Illinoian times—an ice dam stretching across the lower valley. The entire valley was laked and finally the water found its way across a saddle at Coxville into a tributary of Leatherwood Creek. This ice dam would also account for the Bridgeton terrace. He indicates that at some time during the

[6] *Loc. cit.*

glacial age the Wabash waters may have found their way through this valley and Atherton Island was truly insular. He says that "during the climax and retreat of the Wisconsin Ice Sheet, the valleys of the Wabash and its tributaries were aggraded to the present terrace level. For a time the present mouth of the Raccoon was blocked by ice and the stream flowed over the terrace directly to the Wabash. By final withdrawal of the ice margin from the Shelbyville moraine the northern outlet was left a little lower than the Rosedale divide, and the present conditions came into existence".

Geographers are agreed that the region drained by Raccoon Creek was uncovered by the Wisconsin Ice Sheet while the present mouth of Raccoon Creek near Montezuma was still covered with ice. The Wisconsin Ice Sheet came in lobes, following the valleys in the main, until a great enough thickness was attained to override the divides. As the ice melted and receded to the north, it probably reformed into its original lobes. Thus the river was blocked after the valley was freed. McBeth[7] advances strong argument to prove that the whole melting of the Wisconsin Sheet was from east to west.

It is evident, therefore, that Raccoon Creek must have followed its southwesterly course during the time of the Wisconsin Ice Sheet. It follows that the present deflection of the stream to the north is Post-Wisconsin.

It would seem probable, however, that there was a valley formed before the deflection of the stream. The present sand dune divide would not force the creek over a very high saddle. This valley might have been formed in any of a number of ways. I will indicate a few of them.

During the waning of the Wisconsin Ice Sheet it is possible that a stream found its way out along the margin of the ice into Raccoon Creek. Such a stream would carry a load sufficient to build up a very level plain between the ice and Raccoon Creek.

It is possible, as Dryer suggests, that some of the Wabash waters at one time found their way through this channel. The present width and depth of gravels would not indicate much more than overflowing back water, however.

It is possible, of course, that the original cause of deflection was an ice dam—as previously suggested. I do not believe, however, that it is necessary to explain the Bridgeton terrace by this dam. The Bridgeton terrace might well be considered as a part of the Terre Haute terrace and explained as glacial outwash with it.

Lastly, it is possible that the divide between a north-flowing branch of Leatherwood Creek and a south-flowing branch of Raccoon Creek was low enough that the waters of Raccoon Creek were forced over it, as the valley filled with sand, in Post-Wisconsin times. This would occur gradually, of course, probably for years only at the time of high water, until a permanent channel was effected.

I have given these theories in the order of their probability, in

[7] McBeth, W. A., "Development of the Wabash Drainage System and the Recession of the Ice Sheet in Indiana", Proc. Ind. Acad. Sci., 1910, pp. 184-192.

my own judgment. The marginal stream theory seems reasonable to me, while the last mentioned theory occurs only as a possibility.[8]

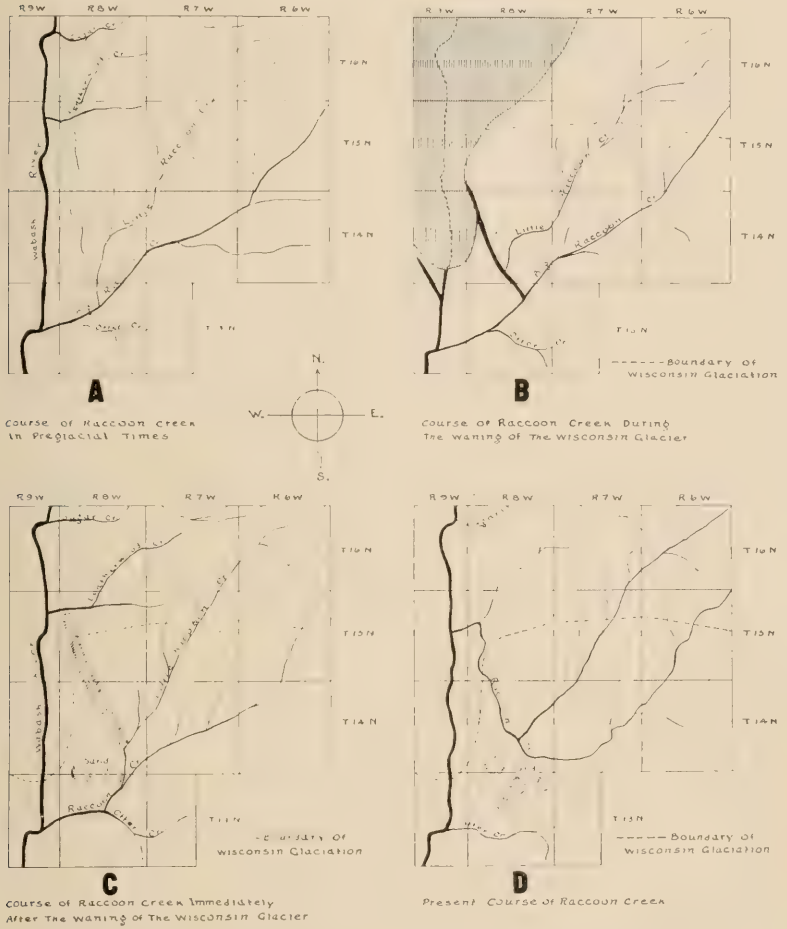

Fig. 1. *A*—the course of Raccoon Creek in pre-glacial times; *B*—the course of Raccoon Creek during the waning of the Wisconsin Glacier, with the boundary of Wisconsin Glaciation; *C*—the course of Raccoon Creek immediately after the waning of the Wisconsin Glacier; *D*—the present course of Raccoon Creek, with sand deposits indicated.

As already indicated, I believe that the immediate cause of the change of drainage in Post-Wisconsin times lies in the sand dune topography of the region. The two valleys are filled with sand and

[8] Since presenting this paper I have received the suggestion from Mr. W. M. Tucker of Indiana University that this region might be similar to Scioto River district in southern Ohio, which has been described in a folio of the U. S. Geol. Survey. In that case we must presume that during the glacial period the Wabash built up a terrace of sufficient size, in itself, to bar the entrance of the minor stream.

there is a strong sweep of wind from the southwest—five or six miles without interruption. At present the dunes are from 15 to 20 feet high and rather firmly established. Before vegetation was abundant there must have been very ready movement of the sand. Weather records at the Terre Haute station tend to verify our statements as to the wind direction.

Sand deposits have been previously mentioned in this region. McBeth[9] has a pamphlet on the sand deposits of Vigo County. Shannon[10] mentions this district as one of the five areas of sand deposition in the state. I have not found any previous suggestion, however, that the dune topography has affected the drainage in any way.

There is a well record worth attention just south of the present turn in Raccoon Creek. Bits of driftwood and vegetation were found at a depth of 88 feet in connection with loose gravel and silt. This "made land" would, of course, indicate recent filling.

Summary.—It would seem, therefore, that Raccoon Creek was once a rather large river flowing southwest across Indiana into the Wabash just above the present site of Terre Haute (figure 1). During glacial times a valley was formed parallel to the Wabash, either (1) by the escape of a glacial stream along the edge of the ice while the Wabash was still covered, (2) by overflow waters of the Wabash, (3) by the ice damming of Raccoon Creek, or (4) by the lowering of the divide between Leatherwood and Raccoon creeks. Of course the valley might have been formed in two or more of these ways.

In Post-Wisconsin times the Raccoon has been turned into this valley by the filling of its course by wind blown sand. The channel is now obliterated by sand and loess deposits.

[9] McBeth, W. A., "Loess and Sand Deposits in Vigo County", Proc. Ind. Acad. Sci., 1915, pp. 185-188.

[10] Shannon, C. W., "The Sand Areas of Indiana", Proc. Ind. Acad. Sci., 1911, pp. 197-210.

THE DEVELOPMENT OF SOIL SURVEY.

T. M. BUSHNELL, Purdue University.

The ancients believed in the elemental nature of earth, air, fire and water. This simple concept has been replaced by complex, modern science, yet to the average person, soil is simply "dirt". Simple, contrasting adjectives such as "good or bad, wet or dry, hard or soft, sand or clay, and black, white, red or yellow" are commonly used and seem sufficient. Men may agree that soil is a simple subject until they have some examples before them and find they can not agree as to what is "black" or "clay" or even say what the soil is.

Before attempting any sort of definition of the soil, mention will be made of the beginnings and growth of the Soil Survey idea. Students of ancient history find references to soil studies which might be considered the germs of the idea. However, when the modern period of the study of nature arrived, soil science, as such, seems to have been neglected. Apparently no great scientist worked in this field so intensively as in other branches of study, and much soil knowledge came as by-products of botany, zoölogy, physics, chemistry, geology, etc. Perhaps this neglect resulted because the agriculture on soils of the civilized world was the outgrowth of centuries of use, and this use had greatly modified the natural soils. Many soil studies have been designed to learn how to increase crop yields, rather than to learn to know the soil itself. Numerous physical and chemical studies have been made—not of the soil—but of soil materials, disturbed and mixed, often without knowing what soil or what portion of a soil was being investigated. The results were little more informing about the actual soils than the analyses of odd bits of animals would be. The need of knowing the "kinds of soils", and of having a strictly scientific taxonomy of soils was gradually recognized. One of the earliest forms of classification was based on the natural vegetation of the land and gave rise to such terms as "prairie", "walnut", or "piny woods" lands.

Probably the most extensive and best system of soil classification until recent years, was an outgrowth of geology, and took into consideration physiography, drainage, lithological nature of the soil-forming materials, and some of the processes by which they were accumulated. Thus we use such expressions as "upland or bottom", "limestone or sandstone", and "glacial or residual" soils. While these factors are all of importance, especially in connection with the geographical distribution of soils, this mode of attack failed to get at the fundamental relationships of soils.

Dr. C. F. Marbut, of the U. S. Bureau of Soils, stated in 1921 that there was "a complete lack throughout the world, until less than 40 years ago, of a knowledge of the real characteristics of soils, and the lack of this knowledge in this country until less than 20 years ago". European scientists, especially those in Russia, are credited with the first understanding of soils. A soil map of European Russia, published in 1901, embodied some of the earliest soil survey work of the

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

world. About the same time an independent start was being made in this country where the recognized pioneer is Prof. Milton Whitney, Chief of the U. S. Bureau of Soils.

Russian soil survey progressed until interrupted by the war and has since been resumed. In the United States it has grown continuously, largely through work of the U. S. Bureau of Soils, with or without the co-operation of various state agencies. Some states have carried on independent work, and naturally there has been great divergence in the methods and products of the various surveys, but all have classified lands upon some basis and have shown the location of the classes on a map. That is the essence of soil survey. It is primarily field work designed to identify, describe, classify, correlate and map soils. In recent years the tendency is to enlist the aid of all branches of science which have any contact with the soil and to consider correlative laboratory work, experiments and extension as integral parts of a complete survey.

What, then is the true soil? Marbut defines it as the weathered surface horizon of the earth's crust, which forms a natural body, developed by natural forces acting through natural processes upon natural materials. The soil embraces that layer of the earth's surface having the most abundant and complex flora and fauna. It is the meeting ground of the organic and inorganic materials. Soil is dynamic and everchanging. It passes through youth, maturity, old age, rejuvenation and transmigration. The one-sided observation of soils, chiefly from the top, contributed to general ignorance of their nature. Cultivation mutilated the true soil. Soil survey workers went a little deeper with soil augers and learned something from the mixed and displaced material they brought up, but made the mistake of limiting the study to three feet or some other arbitrary depth. Even today this idea persists in the form of analyses of the surface three feet divided into arbitrary layers. Yet who would attempt to study corn by cutting three feet off of the tassel end of stalks standing from two to ten feet high, then subdividing these lengths into segments for analysis?

A scientific classification of soils must be on the basis of features of the soils themselves, rather than on the growth they support or the way the materials accumulated. The characteristic features by which a soil type or species is recognized and identified and classified are embodied in the natural soil section extending from the surface to the unweathered parent materials, whether it be one or twenty feet below. This soil section is made up of natural horizontal layers which are different from each other but relatively uniform within each, as to color, texture, structure, thickness and chemical composition. Each soil type has a definite number of layers in the same relative arrangement, and is derived from geologic parent materials of a certain character.

A soil series or genus includes soil types which are practically alike save in the texture of the upper layers. Formerly, soil series were grouped into provinces which corresponded to certain geological features of the country, but a more scientific classification results from grouping the series into families according to features of the soil sec-

tions which are the mature expression of various sets of climatic conditions. Mature soils develop where topography favors drainage and aeration and the accumulation of weathered products. On rolling or eroded lands the soil section may be immature, and on flat lands it may have passed through maturity to old age, marked by strongly leached surface and so-called "hardpan" layers. In associated lands with a high water table there is preservation, rather than weathering, of the parent materials, and accumulation of organic remains. Weathering of alternately wet and dry lands proceeds in a complex manner.

The chief factors of climate affecting soils are conditions of heat and moisture. In this country east of the Rocky Mountains there are two or three temperature zones and three or four zones according to rainfall and humidity, and as the resultant of prevailing climate Marbut has described ten distinct soil families. These families may be grouped into two soil orders—the arid and the humid. The soils of the arid order are marked by a zone of carbonate accumulation in the soil section, while those of the humid order lack this zone, but are leached and often acid.

At present a soil survey embraces several phases. First is the strictly research work designed to collect enough data to serve as a basis of a natural and sound classification, and provide adequate nomenclature so that all soil science may be related to soil types. A part of the records of soil survey is in the form of maps, and this map making is one of the chief functions of the field workers. A soil survey includes some physical and chemical tests in both field and laboratory. Since the work is supported chiefly by agricultural appropriations it is expected to justify its existence by ultimate benefits to the farming interests. Efforts to be of more immediate benefit take the form of aiding the interpretation of results on experimental fields and of showing where these results apply, or of furnishing data to extension workers. However, most soil survey workers feel that an attempt to occupy middle ground between the "practical and scientific" promises little progress in either direction, and believe that sound soil science is a prerequisite to sound advice on practical soil problems. It is hoped to collect and organize soil facts into a science comparable with other branches of knowledge. Just as we receive aid from geologists, botanists, bacteriologists, etc., they should be benefited by a fund of exact knowledge whenever the soil is involved in their problems.

In Indiana the soil survey has passed through several stages. The U. S. Bureau of Soils mapped ten counties between 1901 and 1908. Beginning about 1907 the State Geological Department carried on work under the name of "Soil Survey" which eventually covered most of southern Indiana. In this the classifications were based more on geological formations than on soil, and the mapping was very general. In 1912 the Bureau of Soils resumed work in the state, now in co-operation with the State Geologist. Under this arrangement sixteen counties were mapped in the central and northern part of the state. It includes some very good work needing little revision to bring it up to date. Nothing was done in 1918.

In 1919 the U. S. Bureau of Soils began co-operation with the Soils and Crops Department of the Purdue University Agricultural

Experiment Station, which also carries on the experimental and extension work linking the soil survey with the agriculturist, who is the one most interested in the soil. Under this arrangement six counties have been worked, though but one is published. Such rapid development of new ideas concerning the nature and classification of soils has been made in the last few years that delays in publication permit the reports to be put in the most up to date form. We are now emerging from the transitional period and hope to proceed on a more logical and permanent basis with the work of knowing and mapping the soils of Indiana.

A CASE OF STREAM PIRACY NEAR GREENCASTLE, INDIANA.

ERNEST RICE SMITH, DePauw University.

In the course of topographic mapping by the class in General Geology, DePauw University, in the fall of 1922, the following case of piracy was noted and studied by the students mapping this area. I desire to express my appreciation to Miss Helen I. Tucker and Mr. Robert L. Allen of the class in Field Geology, 1923, for their careful topographic map of the area. This area deserves attention, not be-

Fig. 1. The approximate drainage relations before piracy began.

cause of the magnitude of the phenomenon involved, but as an evidence of the general presence of important geological phenomena, even in areas which seem very bare of certain phases of geologic interest.

As noted in text books of Geology, conditions are ripe for piracy, where two adjacent drainage systems or parts of the same drainage system have unequal opportunities in the struggle for existence. Any factor which gives one stream the advantage over another stream is thus a contributing cause to piracy. Such factors may be: steeper gradient, greater rainfall, less resistant rock, etc. A complete study of any case of piracy should involve not only a statement of the physiographical history of the piracy, but also the points of superiority of the one drainage system over the over. In the present case, the physiographical history is so plainly written by the hand of nature,

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

that he who is geologically trained may read with ease. The reason for the superiority of the one stream over the other is not so indubitable.

In the NW. ¼, SW. ¼, Sec. 15, Tp. 14 N., R 4 W., on the Arnold farm, there is a stream flowing in a general northerly direction, dividing into an east and west fork at the north fence of the Arnold farm. The east fork is an intermittent stream; the west fork is fed, in its main branch, by a limestone spring which flows throughout the year. In figure 3, this branch is shown as a permanent stream and so it would be, but for the swallowing of the water in its lower course by the numerous limestone joints. At the spring, the limestone is not covered by as great a thickness of glacial till as farther down stream. It is therefore

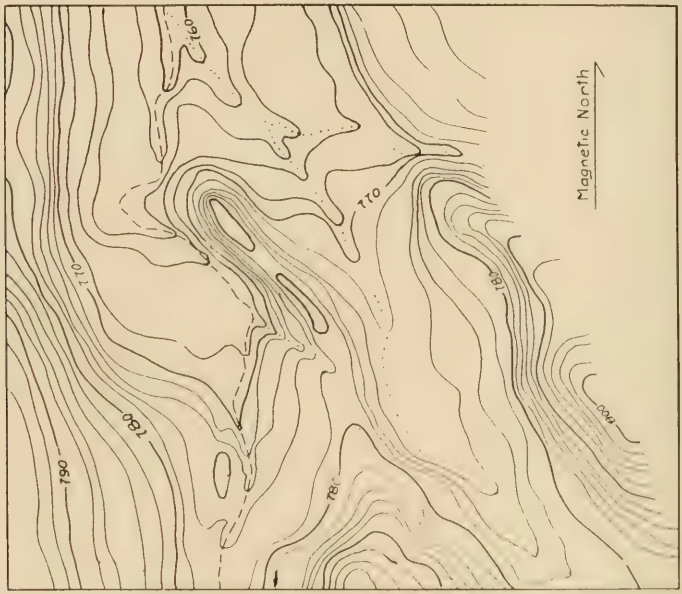

Fig. 2. An intermediate stage between that shown in figures 1 and 3 in the drainage relations.

believed that in the earlier history of the west fork it was a true permanent stream due to the spring and that the water did not then lose itself in the joints, where its flow would give the west fork the advantage over the east fork. Therefore a branch of the west fork would have an advantage over a branch of the east fork.

Shortly above the junction of east and west forks, between the forks, rises an elongate oval hill about 20 feet above the level of the west branch. This hill is entirely surrounded by valleys. It is composed of boulder clay and, except for its marked oval form, is of the Indian-mound type. Immediately to the south of the hill, an intermittent branch joins the main west fork on the east. Up stream, this branch runs first in a general east-west direction, then when well beyond

the oval hill, the course swings around toward the south. From this bend, toward the north, east of the hill is a broad valley running down to the main east fork, but without a stream in it. This streamless valley serves to isolate the oval hill from the main valley wall on the east as does the east branch of the west fork from the valley wall on the south.

In figures 1, 2 and 3, the attempt is made to illustrate what is believed to be the drainage development of this hill and the surrounding

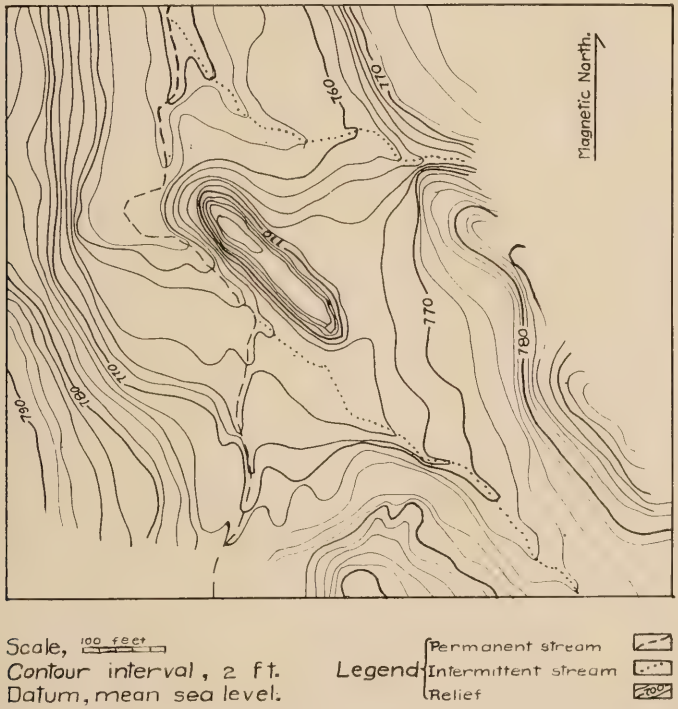

Fig. 3. Present drainage showing the progress of piracy as begun and illustrated in figure 2.

valleys. Figure 1 shows the approximate drainage relations before the piracy began. The west fork has not bifurcated; a branch runs down to the east of the oval-shaped hill (now only a point running out from the south wall), joining the east fork. Figure 2 tells substantially the same story, except that there is a gully cutting off from the west fork which in time will behead the branch of the east fork. Figure 3 shows present drainage relations, the gully having completely separated the hill from the south wall and beheaded the other branch.

THE SILENT ELECTRIC DISCHARGE AND ITS EFFECTS ON GASES.

R. H. GEORGE and K. A. OPLINGER,
Engineering Experiment Station, Purdue University.

In order to determine the causes for the erratic behavior of gases when subjected to a silent electric discharge the Engineering Experiment Station at Purdue University has been conducting an investigation of alternating current discharge in an attempt to obtain further knowledge of its mechanism. This investigation has continued over a period of about four years in conjunction with the problem of the fixation of atmospheric nitrogen by the silent electric discharge.[1]

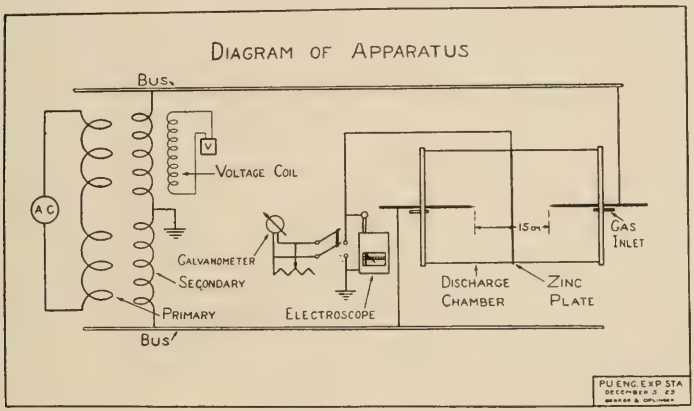

Fig. 1. Diagram of a corona discharge apparatus and power supply circuits.

In the beginning only the discharge in air was considered but the problem here was so complex that an attempt was made to simplify it by studying the discharge in the component gases. The work set forth in this paper is a résumé of recent investigations in the two gases, nitrogen and oxygen.

The discharge chamber as shown in figure 1 is made up of glass plates cemented together at the edges and to the bakelite end pieces. The gas was admitted at each end and allowed to pass out through a small opening in the top near the center of the chamber. The needles used were made by drawing down a 2 mm. glass tube and sealing into it a short piece of tungsten wire 0.27 mm. in diameter which extended out beyond the glass a distance of 3 mm. and was carefully ground to a point. The needles were then centered in the chamber with a distance of 15 cm. between points. Connections were made to the tungsten points by filling the glass tubes with mercury.

[1] See Bulletin No. 9, Engineering Experiment Station, Lafayette, Indiana, for a detailed description of this work.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

In nitrogen a very beautiful discharge is obtained which extends from one needle to the other and is made up of many fine streamers of glow discharge.

The discharge in oxygen is scarcely visible up to the sparking potential, which is almost double that of nitrogen. We were unable to obtain a photographic record of this discharge as even the slight glow of the points failed to show up on the photographic plates.

The discharge in nitrogen with an insulated zinc plate placed midway between the two needles is represented in figure 2. This picture has been retouched and the uneven joint in the center of the discharge chamber is cut out. The presence of the plate increased the sparking potential about 50 per cent. If the discharge at the point is closely studied it is seen that from the neck of the discharge many small

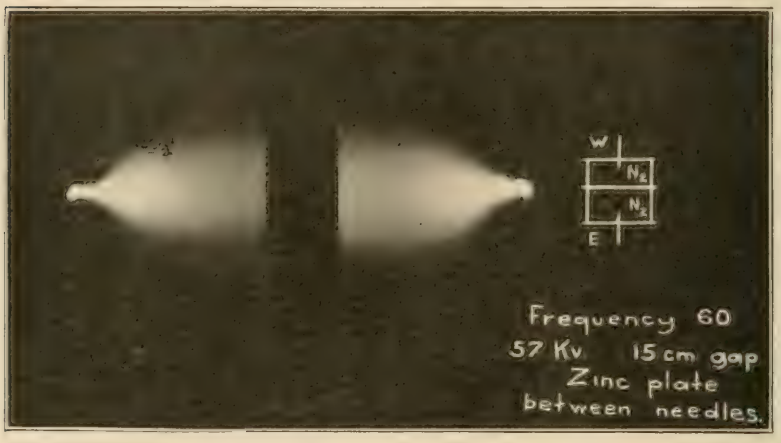

Fig. 2. Discharge in nitrogen with zinc plate between needle electrodes.

branches form at definite intervals. This formation seems to indicate that the discharge is composed of a number of concentric cones.

This structure of the discharge was still further substantiated by a study of the zinc plate after it had been in the discharge for a short time. Sections of the plate were roughened giving the concentric circles shown in figure 3. The light portion represents the roughened surface and the darker portion indicates where the plate retained much of its original polish. Due to the fact that most of the static sparks struck within the inner circle this section is roughened more than any other.

Although the discharge, as represented in figure 2, appears continuous to the eye it is actually made up of two distinct types of discharge, the images of which are superimposed. By means of a special camera[2] these two can be separated and drawn out along a time axis. Figure 4 represents the discharge in nitrogen at 60 cycles

[2] McEachron, Karl B., "Two Photographic Methods of Studying High-Voltage Discharges", Amer. Inst. Elec. Eng., Vol. 42, No. 10, 1923, pp. 1045-1050.

taken with this camera. The scale at the top and bottom gives the number of electrical degrees passed through with respect to time in the direction shown. The negative discharge appears as a line which represents a concentrated glow on the needle point, while the positive discharge gives the characteristic brush extending from the needle

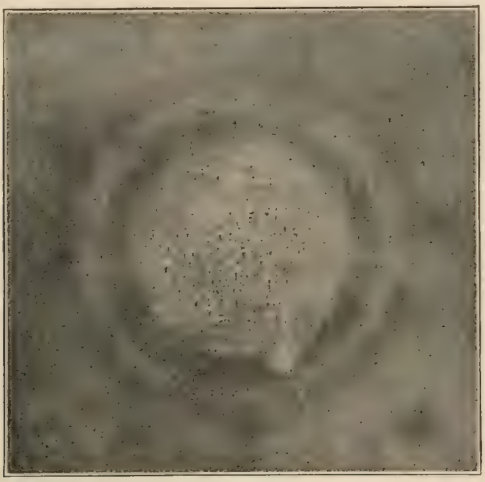

Fig. 3. Photograph of zinc plate showing effects of discharge on the metal.

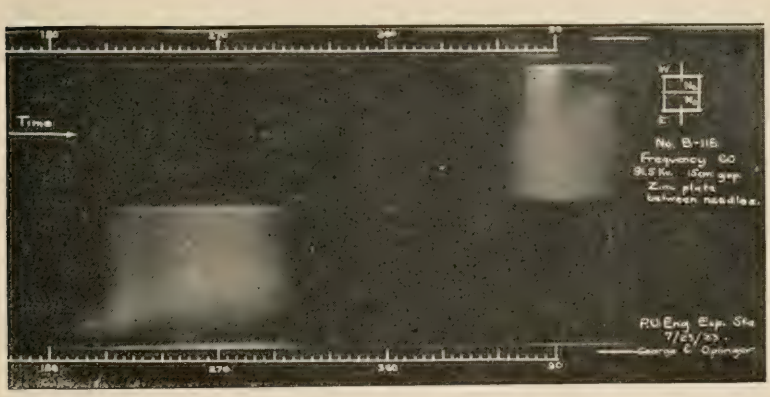

Fig. 4. Corona discharge in nitrogen taken with revolving mirror camera.

point to the zinc plate. In the positive brush, a short distance from the needle may be seen a dark space. This represents a space between the end of the neck and the brush where there is either no radiation or where the radiation is of such wave length that it does not affect the photographic film. Pictures taken without the zinc plate show the luminous discharge extending from one needle to the other.

Experiments conducted by Francis E. Nipher[3] show that this luminous column terminates on the plate and becomes longer or shorter depending upon the distance of the plate from the positive needle.

A 5 mm. hole was made in the center of the zinc plate to see if the corona would pass through this hole to the other needle. It was found that if enough sparks had taken place to ionize the gas sufficiently, the discharge would pass through the hole. By blowing nitrogen in one end of the apparatus, through the hole, and out the other end it was possible to obtain a unidirectional discharge as shown in figure 5. Here the luminous discharge follows the flow of gas through the hole. The positive brush from the W needle is unable to form against the stream of ionized gas flowing through the hole.

During previous work with alternating current discharges it was noted that an insulated plate placed between needle points appeared

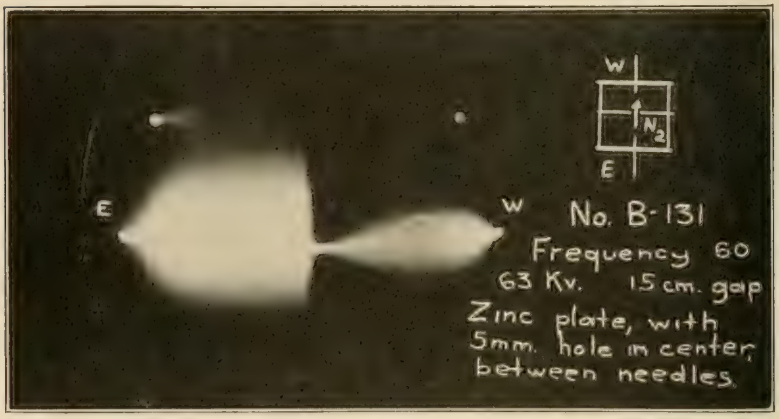

Fig. 5. Discharge in nitrogen passing through hole in zinc plate. Note unidirectional effect.

to pick up a positive charge as small brushes of positive corona would form on the edges of the plate when a spark occurred between the needles and the plate. In order to determine the nature and amount of this charge the zinc plate was connected so that it might either be grounded through a galvanometer or connected to an electroscope as shown in figure 1. With this arrangement the charge on the plate is determined by the electroscope and any difference in the postive and negative discharge current when the plate is grounded is measured by the galvanometer. Some difficulty was experienced in getting an electroscope of sufficient range to read all voltages on the plate with any degree of accuracy.

Two sets of tests were made with each gas, one to determine the effect of voltage on the plate current and potential when the gas is fresh and the other to determine the time effect of discharge with an

[3] Experimental Studies in Electricity and Magnetism, Blakiston's Sons Co., Philadelphia, 1914, p. 3.

enclosed volume of gas. Before taking data with different gases, the gas was blown through the apparatus for approximately one hour at the rate of about 5 liters per minute. In the case of tests with the same gas, 30 to 45 minutes was considered long enough to remove all traces of contaminated gas.

Figure 6 gives the results of these tests in oxygen. With gas blowing through the apparatus, when determining the effect of voltage, the readings were taken as rapidly as possible, the plate being grounded only long enough to take a reading on the galvanometer. From the curve it is seen that the current continues to increase in a negative direction with an increase in voltage until the sparking potential is

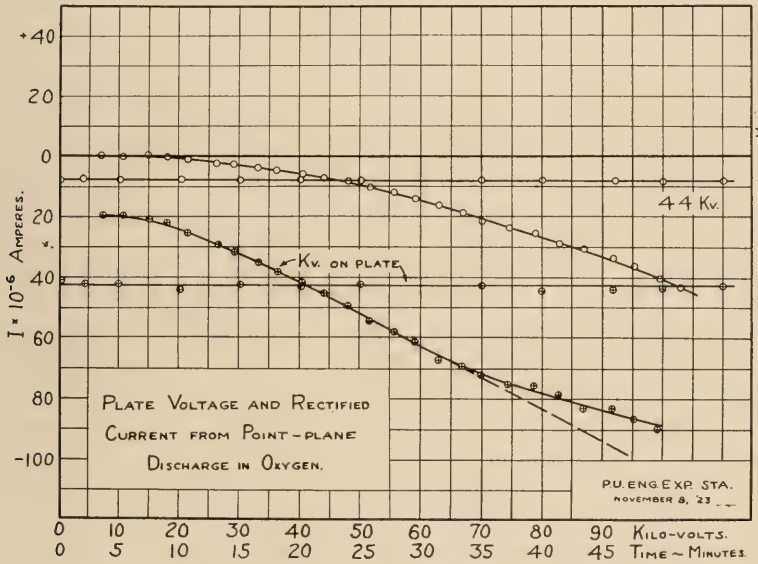

Fig. 6. Rectified current in oxygen.

reached. The effect of time upon the current is very slight, as shown by the other curve taken at a constant voltage of 44 kv. A charge as high as 4 kv. was found to exist on the plate.

The results with nitrogen were quite different and are given in figure 7. Two sets of tests as shown by the solid and dotted curves, were made upon the same day, and check fairly close. With an increase in voltage the negative current increases until at 37 kv. a very definite change in characteristics of the gas takes place. This is shown by the scattering of the points at this portion of the curve and by the sudden decided decrease of the negative current. As the voltage is still further increased the current falls to zero and becomes positive at the sparking potential.

In these experiments the voltage readings were unsatisfactory due to the large variation in plate voltage. A high voltage electroscope

was used which was not sensitive at the low values. The maximum negative potential which the plate attained was 7 kv. with an impressed voltage of 30 kv. between needles, which means that the voltage

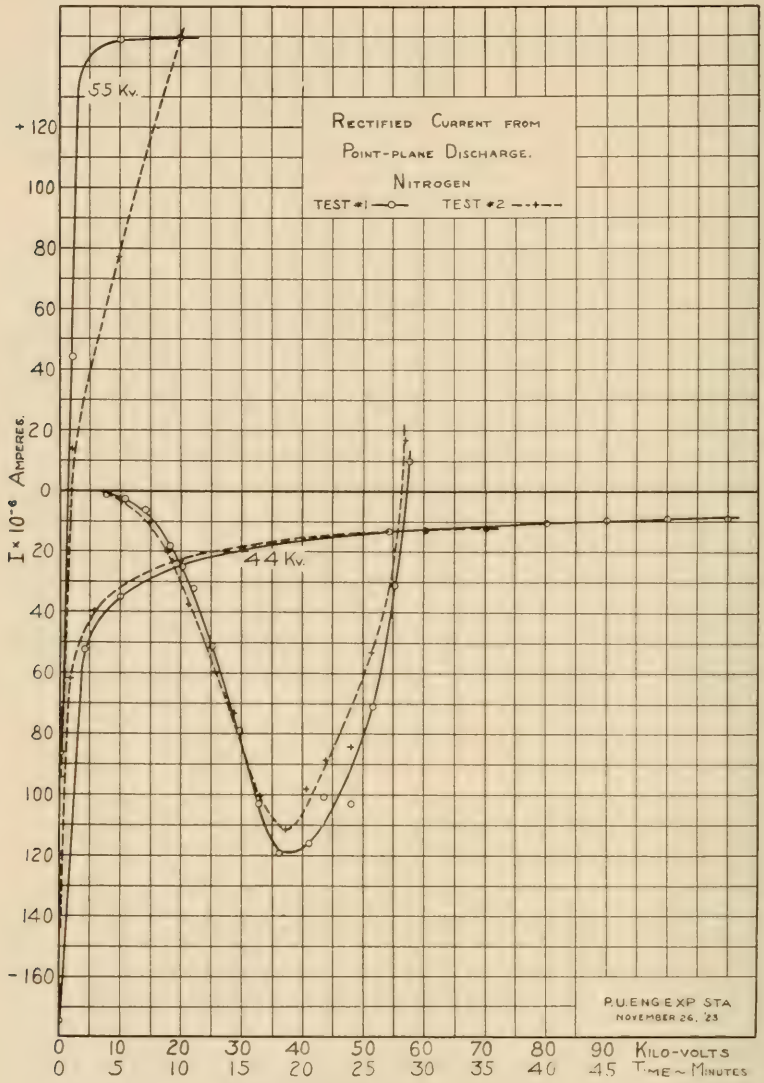

Fig. 7. Rectified current in nitrogen.

from the negative point to the plate was 8 kv., and from the postive point to the plate was 22 kv. with the same current flowing at each needle.

TABLE I.—VOLTAGE DISTRIBUTION BETWEEN ELECTRODES AND PLATE

Potentials in Kilovolts				Plate to Ground Current $I \cdot 10^6$
Between Needles	Plate to Ground	Needle to Plate		
		Positive	Negative	
7.1	−0.76	4.31	2.79	− 0.29
14.1	−1.77	8.82	5.28	− 5.5
21.1	−2.67	13.22	7.88	−20.8
25.5	−3.0	15.75	9.75	−30.9
32.7	−3.32	19.67	13.03	−54.9
40.8	−2.02	22.43	18.38	−68.0
47.5	−0.95	24.7	22.8	−25.5
51.5	+0.87	24.62	26.88	+19.6
54.0	+2.02	24.98	29.02	+173.2

Table I shows the voltage characteristic for nitrogen which was slightly contaminated. The low plate voltages which fell within the range of one electroscope were due to contamination.

It is unfortunate that we were unable to measure the total current supplied to the needles and thus determine whether there was a large increase in current when the voltage between the positive needle and plate reached 24 kv.

The large negative current at 44 kv. decreased very rapidly with time as brought out by the curve of figure 7, but does not reverse. However, at 55 kv. the current reversed very soon after the voltage was applied and attained a very high positive value.

The following factors may assist in the production of the phenomena observed in the case of nitrogen:

1. Electron emission from the zinc plate by postive ion bombardment.
2. Ionization by collision with positive ions.
3. The formation of large negative ions due to activation of the gas.
4. Photoelectric effect produced by the action of the ultraviolet light on the zinc plate.

From the voltage data it would appear that numbers 1 and 2 were the controlling factors, but they do not explain the initial voltage and current characteristics found when the gas has previously been subjected to the discharge. Evidently the gas undergoes a change, probably in the positive discharge, from which, it does not recover for several hours. The question of whether the molecules acquire the ability to pick up electrons from the negative discharge and thus decrease their mobility must be left for future investigation with high-voltage direct current.

SUMMARY AND CONCLUSIONS.

1. The sparking potential between points in fresh nitrogen is roughly 60 per cent of that value for oxygen under the same conditions.

2. If nitrogen has been subjected to heavy sparking its sparking potential is reduced and remains so for some time.

3. The presence of a metal plate midway between the electrodes increases the sparking potential in nitrogen from 30 to 60 per cent but has no appreciable effect in the case of oxygen.

4. The sparking potential with a 5 mm. hole in the metal plate is only slightly greater than that of the gap alone.

5. If a metal plate is placed midway between points discharging in nitrogen, it acquires, at low potentials, a strong negative charge, but if the voltage is increased sufficiently, the sign of the charge is reversed. If the discharge takes place in oxygen the negative charge acquired by the plate is very much less than for nitrogen, but continues to increase up to the sparking potential.

6. The effect of time of discharge at constant potential, on an enclosed volume of nitrogen, is to cause a reduction in the initial negative charge on the plate, which under certain conditions may change sign and become positive.

7. Oxygen is consistent in its behavior under the influence of the discharge.

8. The discharge in nitrogen takes a number of forms depending upon potential, previous history of the gas, time of discharge and material placed in the path of the discharge. This indicates the formation of an activated nitrogen whose electrical properties are greatly different from those of the unaffected gas.

9. Measurement of the charge acquired by a metal plate placed between needles discharging in nitrogen might possibly be used to determine when nitrogen is in the proper state to unite with other elements.

A more complete account of this work together with much other material will be found in an Engineering Experiment Station Bulletin to be published in the near future.

The gas used in these experiments was kindly donated by the Cleveland Wire Division of the National Lamp Works through the courtesy of Mr. B. L. Benbow.

THE ELECTROMETRIC TITRATION OF BORIC ACID IN THE PRESENCE OF POLYPHENOLS AND ORGANIC ACIDS.

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It has been recognized for some time that boric acid is too weak to be titrated alone. The addition of certain polyhydroxy-organic compounds, such as mannitol, permits of an accurate titration of this acid. In a previous article by the authors,[1] there was published the results of titrations of boric acid in the presence of a number of polyalcohols and sugars. The present work, an extension of the previous investigation, presents the results of titrations in the presence of two other types of polyhydroxy-organic compounds; namely, polyphenols and hydroxy-acids.

Although it has never been definitely established, the usual assumption is that the organic substance unites with the boric acid to form a complex acid, which is ionized to a much greater extent than is the boric acid alone. Consequently, the complex can be titrated with a standard solution of a base, using phenolphthalein as the indicator.

As in the previous investigation, the titrations were made with an electrometric apparatus. By this means it is possible to obtain the hydrogen ion concentration, or, what is more generally desired, the pH value after each addition of basic solution. Plotting the pH curve, with milliliters of base as abscissas and pH values as ordinates, provides an easy means of following the course of the neutralization.

Previous Work.—The bearing of previous work on the present investigation was discussed, in general, in the authors' earlier paper. Specifically, it should be mentioned that it was Magnanini[2] who made the first observations that various hydroxyacids increase the electrical conductivity of boric acid to a marked degree. In recent years Boeseken[3] and his students have studied the effect of a large number of polyhydroxy compounds, including polyphenols and hydroxyacids. He concluded that a complex acid, much stronger than the components, is formed, and that, for the formation of such a complex, two OH groups must be situated on the same side of the adjacent carbon atoms to which they are attached. When such a configuration does not exist, as with the beta and gamma polyhydroxy arrangements, a negligible or slightly negative effect on the conductivity was observed.

Present Work.—It has been the general practice to add either mannitol or glycerol to boric acid before making a titration of the latter. The authors have pointed out in their previous article that invert sugar and manna are more economical than either mannitol or glycerol for this purpose. The work of Manganini and Boeseken indicated that there were still other substances, among the polyphenols and

[1] Ind. Eng. Chem., *16*, 123 (1924).

[2] Gazetta, *21*, 9 (1891); Z. Phys. Chem., *11*, 281 (1893).

[3] Rec. trav. chim., *40*, 553, 578 (1921); *37*, 130, 165, 178 (1918); *35*, 211 (1916); *36*, 167 (1917); Ber., *46*, 2612 (1913).

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

hydroxyacids, which increased the conductivity of boric acid. The present work was undertaken, therefore, having as its object the determination of the possibility of using any of the substances just mentioned in the titration of boric acid.

Apparatus and Materials.—As in the previous work, the Wendt Electro-titration apparatus was used, with the same electrodes and hydrogen purification train. Moreover, the boric acid and sodium hydroxide solutions were the same as previously described. The organic reagents were used as purchased, inasmuch as conditions simulating those of an industrial laboratory were desired.

Procedure.—Except in the case of lactic acid, the procedure consisted in the titration of a definite volume of the boric acid solution to which a weighed quantity of the organic substance had been added. In order to have the various titrations on a comparable basis, a definite ratio of four molecular weights of the polyphenol to one of boric acid was maintained. This was modified, in the case of the acids, to one equivalent weight of the organic acid to one of boric acid, the reason for the change being given under the discussion of the results obtained. Phenolphthalein was present in each titration, this indicator being the one generally used in volumetric determinations of boric acid. Errors due to temperature changes and to the absorption of carbon dioxide are neglected in view of the purpose of the work.

Experimental Data.—Although the original data are not included, the curves, plotted from these data, are shown. The usual methods are employed in the plotting of these curves, the pH values being the ordinates and milliliters of standard base the abscissas. The curve for boric acid alone has been repeated on each figure in order that the effect of the organic substance on the neutralization curve can be visualized. The curve for the titration in the presence of mannitol is also shown on figure 1, an effect similar to that of mannitol being the desirable effect.

Polyphenols.—The polyphenols selected were pyrocatechol, o-$C_6H_4(OH)_2$, and pyrogallol, 1, 2, 3-$C_6H_3(OH)_3$. The work of Boeseken[4] indicated that the difference between the conductivity of the mixture and the sum of those of the components ($Kx10^{-6}$) was in the case of glycerol, 9; mannitol, 685; pyrocatechol, 516, and pyrogallol, 573. Judging from these data alone, it would appear that the polyphenols promised an efficiency approaching that of mannitol and far in excess of that of glycerol. In the acid range, as indicated in figure 1, the results of the titrations were as expected, but upon approaching and passing the neutralization point, the expected upward break in the curve did not take place. With pyrocatechol, a yellowish-brown coloration developed during the titration, masking the color change of the indicator. A decided downward drift was noted in the readings of the millivoltmeter if the solution was allowed to stand after completing the titration. Similar developments were noted with pyrogallol.

Hydroxyacids.—Of the various acids which Boeseken found to increase the electrical conductivity of boric acid, some are recognized

[4] Ber., *46*, 2612 (1913).

at once as belonging to the group known as hydroxyacids, such as lactic, tartaric, etc. Others showing a positive effect, such as oxalic and malonic, one would not so classify. Boeseken has explained the action of the latter by assuming that we have to do with a polyhydroxy-compound formed by the hydration of the carboxyl group at the carbonyl oxygen so that the OH groups are favorably situated. Several members of each of these types of acids were selected.

In titrating boric acid in the presence of another acid stronger than itself, one would expect a pH curve quite different from those

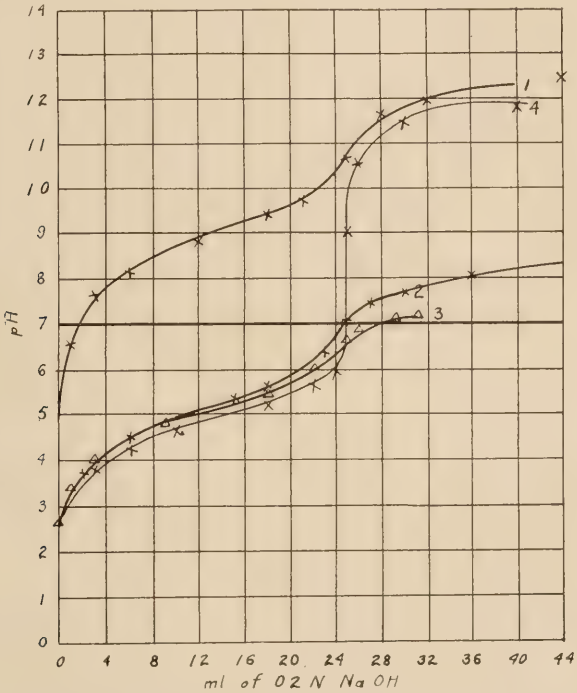

Fig. 1. Titration of boric acid (50 ml. of a solution 0.0994 N) in the presence of polyphenols: (1) acid alone, (2) pyrocatechol, (3) pyrogallol, (4) mannitol.

obtained in titrating boric acid in the presence of a polyalcohol. In the latter case boric acid is the only constituent being neutralized, and the general effect of the polyalcohol is to produce a complex acid more highly ionized than boric acid. This effect becomes apparent in a considerable drop, along the pH scale, of the initial portion of the neutralization curve and in the appearance in it of a comparatively long vertical portion. The titration of a mixture of boric and lactic acids, for example, is a different matter. In studying the electrical conductivity of such a system Boeseken had merely to prepare a given mixture and then to determine whether its conductivity differed from the value calculated as the sum of the contributions of each constituent to the total.

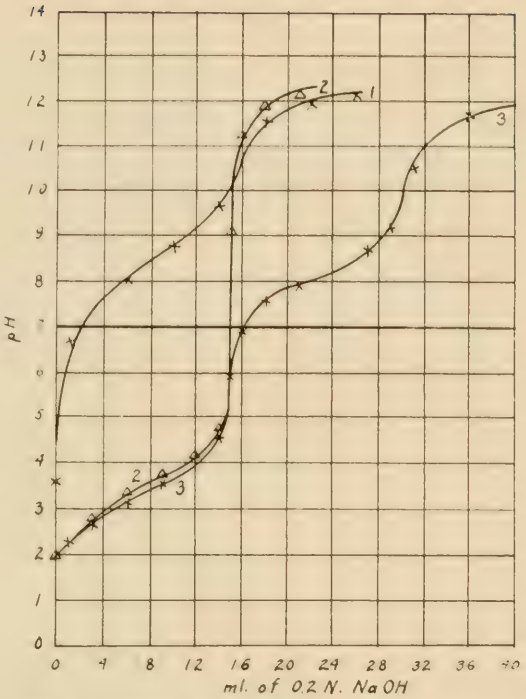

Fig. 2. Titration of boric acid (30 ml. of a solution 0.0994 N) in the presence of glycolic acid: (1) boric acid alone, (2) glycolic acid alone, (3) boric and glycolic acids together.

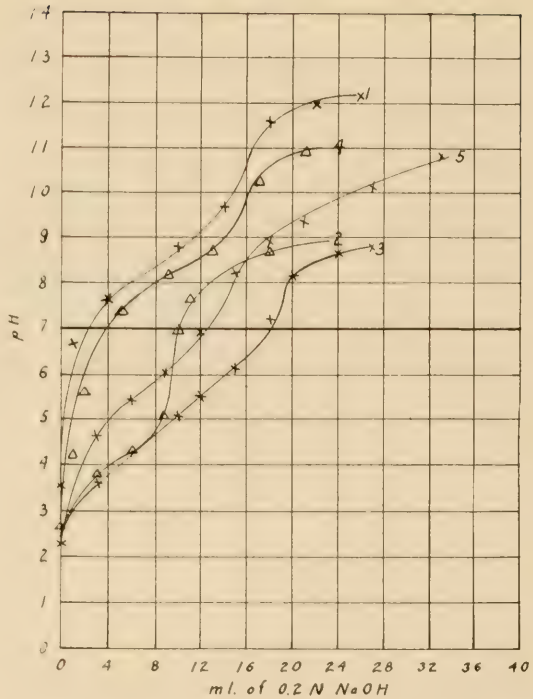

Fig. 3. Titration of boric acid (0.0994 N) in the presence of aromatic acids: (1) 30 ml. of the solution of boric acid, (2) gallic acid alone, (3) 20 ml. of the solution of boric acid together with the same amount of gallic acid used in 2, (4) tannic acid alone, (5) 30 ml. of the solution of boric acid together with the same amount of tannic acid used in 4.

The first titrations attempted indicated that the two constituent acids in the mixture were apparently neutralized separately. With the four to one molecular ratio used with the polyphenols, the two breaks in the curve occurred very close together so that it was considered desirable to select a different ratio. Therefore an amount of the organic acid was dissolved in the solution to be titrated equivalent to the boric acid contained therein. In determining the course of the neutralization for the two acids a titration was run for each acid alone and for the two together.

Titrations were made using the following acids: oxalic, malonic, lactic, glycolic, malic and tartaric of the aliphatic series, and gallic and tannic of the aromatic series, assuming that the properties of tannic acid warrant its inclusion in this class. Salicylic acid was tried but its rate of solution was so slow that the results seemed to be of no value.

The results obtained for glycolic acid are shown in figure 2. These curves are representative of those for the other aliphatic acids, except in those cases involving a dibasic acid, where a small upward break occurs when the first hydrogen of this acid is neutralized. There is evident only a small downward displacement of the first portion of the curve for the organic acid when boric acid is present.

Figure 3 shows the curves for both gallic and tannic acids. It should be noted that the two acids were used on a different basis—20 ml. of boric acid with the gallic acid and 30 with the tannic—and that the curve for boric acid alone is for 30 ml. of the solution. In only one curve—that of boric and gallic—is there a break indicating the possibility of making a satisfactory volumetric determination. In these cases it is evident that the combination of two acids gives a curve distinctly different from that for either one alone. This change in the curve for tannic acid is much greater than the change for any other acid used.

DISCUSSION.

A study of the preceding curves brings out several conclusions regarding the complexes formed by boric acid and some polyhydroxy-organic compounds. These conclusions are concerned primarily with the possibility of utilizing these complexes in the volumetric determination of boric acid and may be stated as follows:

1. In every case the addition of the polyhydroxy-compound produced a downward displacement of the pH curve for boric acid, the degree of displacement varying with the substance used. In general, this may be attributed to the formation of a complex acid which ionizes to a greater extent than does boric acid alone, although in some cases the mere presence of the organic substance might account for the displacement produced, even if no complex were formed. While Boeseken's[5] conductivity experiments may indicate the existence of a complex, the results of the present investigation show clearly that a complex, capable of being titrated accurately, is not necessarily formed.

[5] *Loc. cit.*

2. In no case did the polyphenols or hydroxyacids give indication of the formation of a complex suitable for an accurate volumetric determination of boric acid with sodium hydroxide.

The polyphenols lowered the pH curve of boric acid to a considerable extent in the acid range but did not make the expected rise as neutralization was approached and passed. A search of the literature[6] reveals the fact that among the oxidation products resulting from the exposure of alkaline pyrogallate to the air are carbon dioxide and acetic acid. This fact would explain both the failure of the curve to make the expected rise and the gradual decrease of the millivoltmeter readings upon allowing the solution to stand in the air. A similar reaction may be assumed in the case of pyrocatechol.

The aliphatic hydroxyacids all gave similar curves. Apparently the two acids were neutralized separately just as if no complex had been formed. If the assumption is made that no complex acid is formed, it is merely a matter of the effect of the addition of a stronger acid to the solution of a weaker one. Such a case is discussed by Lewis,[7] who draws the conclusion that the degree of dissociation of the weaker acid—boric—is directly proportional to its dissociation constant and inversely proportional to the concentration of the stronger, glycolic for instance. Application of this conclusion to the present problem makes it obvious that as the amount of the glycolic acid is increased, the borate ions become fewer and fewer, so that practically speaking, the presence of the boric acid can be ignored during the titration of the glycolic. Not until the latter is nearly all neutralized does the ionization of the boric acid again need to be considered. During the latter part of the neutralization the system differs from a solution of boric acid alone only in that it contains in addition the salt of the organic acid neutralized in the first part of the process. The pH curve of the mixture then shows a sharp upward break at the point of neutralization of the glycolic acid, which break is much shorter than that for glycolic alone, however, since the boric acid is now ionizing and hydrogen ions are present. Then follows a gradual rise with a small upward break representing the neutralization of the boric acid.

Both of the aromatic acids, upon approaching the end point of the titrations, developed deep colorations, which would prevent any use of them in ordinary volumetric analysis. Reference to the curves of figure 3 shows that tannic acid is so inactive a substance that no conclusions regarding the nature of the complex formed can be drawn. Gallic acid on the other hand did give evidence of the formation of a complex capable of being titrated, but no application, other than electrometric, could be made of this fact, for the reason stated above.

SUMMARY.

1. The fact that conductivity experiments indicate the formation of a relatively highly ionized complex acid when certain polyhydroxy-organic compounds are added to boric acid does not necessarily indicate

[6] Meyer & Jacobson, "Lehrbuch der Organischen Chemie", *2*, 423 (1902).

[7] "A System of Physical Chemistry", *1*, 423 (1916).

that the use of such compounds will enable one to obtain accurate results in the volumetric determination of boric acid.

2. Accurate titrations of boric acid in the presence of pyrogallol or pyrocatechol seem to be impossible under the conditions described, apparently due to the formation of acidic oxidation products of the organic compounds.

3. Certain organic acids, although believed to form a complex with boric acid, behave during a titration of the mixture of the two as if the process of neutralization involves two rather distinct steps, first, the organic acid, and second, the boric acid.

THE PECULIAR PROPERTIES OF WATER IN LIGHT OF ITS MOLECULAR STRUCTURE.

F. O. ANDEREGG, Purdue University.

Water is such a common substance that we usually take it for granted and it is seldom that we stop to consider the reason for its peculiarity. Occasionally when we examine some of its physical and chemical properties we are struck by their difference from similar properties of numerous organic liquids. The old saying that "oil and water will not mix" is based on actual fact and the reason lies in their molecular structures.

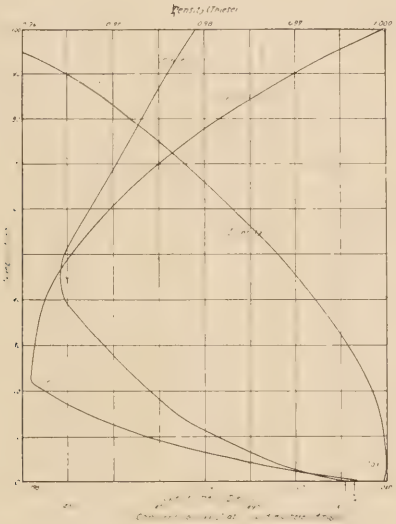

Fig. 1. The specific heat, compressibility and density of liquid water are plotted against the temperature. The data are taken from the 4th ed. of Landolt and Boernstein.

Water has the formula H_2O and hence a molecular weight of 18 and yet it is a liquid at ordinary temperatures with a remarkably high boiling point, and exceptionally high latent heat of vaporization. Its large dielectric constant is coincident with its great solvent and ionizing power for electrolytic compounds. It is, comparatively, a rather dense liquid but its density reaches a maximum at 4° C. On cooling below this temperature expansion takes place and finally, on freezing, a further notable increase in volume occurs. Water is one of the very few substances known, which expands on solidifying. A plausible explanation will be given for this expansion.

The specific heat of water is the largest of any known substance; it varies with the temperature but not regularly. A minimum is reached between 20 and 25° (figure 1). The curve to the left of this point

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

corresponds to the increase in volume on cooling the liquid below 4°. These breaks in the curves indicate points where marked changes occur in the character of the liquid. The compressibility curve shows a similar change.

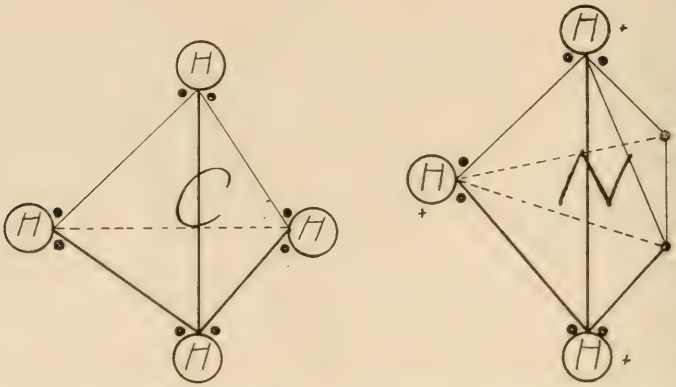

Fig. 2. The methane molecule consists of a tetrahedral carbon atom in combination with four hydrogen atoms. The dots represent the valence electrons which take part in the combination. This is probably the most non-polar molecule known.

Fig. 3. Ammonia, NH_3, is distinguished by a pair of electrons on the surface of the nitrogen which gives to that part of the molecule a negative character. The hydrogens are slightly positive.

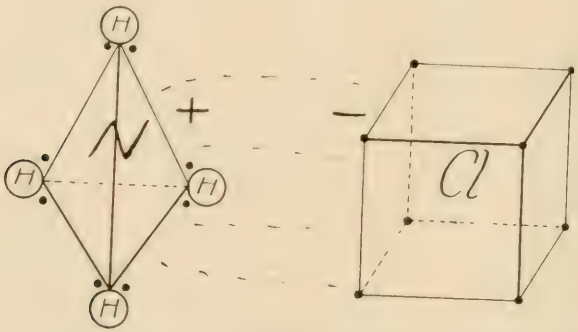

Fig. 4. Ammonium chloride is formed by the action of hydrogen chloride on ammonia gas. The positively charged H from HCl adds onto the extra pair of electrons shown in figure 3 to form the ammonium which is held to the chloride ion by electrostatic forces.

In order to understand the peculiar properties of water it is necessary to understand its molecular structure and for that we must know the structure of the atoms of which water is built up. Although there are a great many details about atomic structure which are in an unsatisfactory state, the theory has developed enough to show the great value, not only in giving us understanding of the properties of most compounds, but also in predicting the new properties which a substance

will acquire under a given set of conditions. The following ideas have been worked out during the past three years at Purdue University in a seminar course for graduate students.

The ideas contained herein are an extension of the Lewis-Langmuir theory of atomic structure which has already proved so fruitful.[1] For the topic under consideration, we need to consider only some of the elements in the first two periods.

Let us consider the simplest hydrocarbon and the hydrogen compounds of nitrogen and oxygen. Methane, CH_4, with a molecular weight of 16 and a very small external field of force is characterized, in addition to its chemical inertia, by a low boiling point, 160° C. Ammonia is NH_3 (figure 3). The nitrogen atom has completed its octet by joining on three hydrogens, each with a single electron. These are probably placed at three of the corners of a tetrahedron. But there is a pair of electrons left over which gives that part of the molecule a negative character. Corresponding to this, one or more of the hydrogens will have a slight positive character; that is, the electrons will be shifted a bit from one or more hydrogens toward the central nitrogen. This results in giving a certain "polarity" to the molecule. Such a polar molecule ought to have much more attraction for other NH_3 molecules than corresponds to its molecular weight, 17. As a matter of fact it boils at —33.5° which is an increase of nearly 130° over methane, although there is an increase in molecular weight of but one. Liquid ammonia is known to be associated. This association gives it a high specific heat and high latent heat of vaporization because considerable energy is used up in separating the complexes that result from these polar attractions.

Chemically, ammonia is very interesting. Bring it into contact with a very polar substance like hydrogen chloride gas. The hydrogen in that compound, as we have seen, is charged positively. When this molecule comes in contact with ammonia the positively charged hydrogen is attracted by the pair of electrons which make that part of ammonia negative (figure 4). This gives a methane-like structure to the ammonium ion which, of course, now bears as a whole the positive charge it picked up with the hydrogen. Then the chloride ion is held by electrostatic forces just as in sodium chloride. Nitrogen forms a great variety of organic compounds and this property of polarity and of adding on a positively charged hydrogen is found there also. This accounts for the formation of such compounds as aniline hydrochloride and the alkaloid complexes with different acids. Incidentally, such addition of polar acid will increase the polarity of the organic compound with important results which will be referred to when we study solutions. Certain metallic ions like silver, copper, cobalt, platinum, etc., due to their structure, have the ability, like a hydrogen ion, of sharing that extra pair of electrons in the ammonia molecule. The result is the possibility of the preparation of an almost bewildering series of ammonia compounds such as the cobaltammines. These are the "higher order compounds" of Werner.

[1] Lewis. J. Am. Chem. Soc., *38*, 762 (1916). Langmuir. ibid., *41*, 1543 (1919). Science, *54*, 59 (1921).

According to these conceptions of the nature of nitrogen, it can take on three or four hydrogens or organic groups. Langmuir[2] calls the number of groups that can be added to an atom its covalence. Carbon, nitrogen and oxygen have the same maximum covalence. The atoms are very nearly the same size as we should expect from their position in the periodic table and, in combination with four groups, they are all probably tetrahedral in shape. This is a modification of

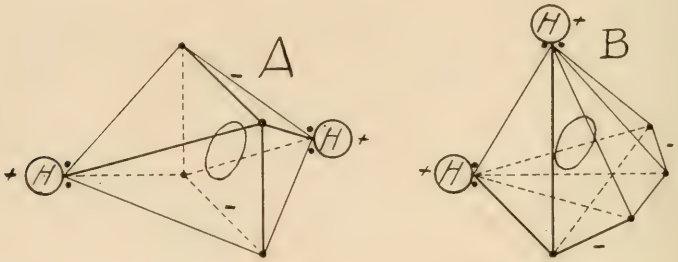

Fig. 5. Two possible forms of the steam molecule or monohydrol are given. In one the hydrogens are adjacent; in the other they are opposite.

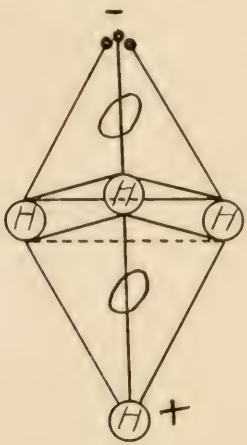

Fig. 6. Dihydrol or liquid water must have a condensed form to explain its great density. Three hydrogens are active in connecting two negative oxygens. Note that this aggregate is still polar, one end negative and the other positive.

the old idea of quinquivalent nitrogen. The polarity of the nitrogen, of course, is diminished according to the length and nature of the organic groups combined with it.

Oxygen combines with two hydrogens to form a liquid at ordinary temperatures. The oxygen atom with its six electrons in the outer shell completes its octet with the electrons from the two hydrogens. But here there are two pairs of extra electrons corresponding to the single pair of the ammonia molecule. That means that half the molecule is more

[2] Langmuir. J. Am. Chem. Soc., *41*, 1543 (1919).

negative than in ammonia and that here the hydrogens are even more positive. The water molecule has, roughly, twice the polarity of ammonia. With a molecular weight of 18 it boils at 100° C. The boiling point of ammonia is about half way between those of methane and water. The other physical properties of ammonia also lie intermediate between those of water and methane.

Association of Water.—The considerable degree of polarity of water is very intimately connected with its peculiarities. When one water vapor molecule (figure 5) comes in contact with another the positive part of the one attracts the negative part of the other and they tend to stick together (figure 6) in a very compact structure. One of the two corners of the aggregate is positive and the other is negative so that this dihydrol, the name that has been suggested for liquid water, is still polar. Dihydrol[3] is often spoken of as liquid water. But liquid water is not dihydrol. It is a solution, especially at higher temperatures, of varying amounts of monohydrol, as steam is often designated, in dihydrol. As the temperature falls, there is an ever increasing amount of ice or ice-like molecules dissolved. Trihydrol is the name that has been given to these aggregates. But as we shall see presently the name, trihydrol, should refer to an arrangement of bondings between molecules rather than to the total number of molecules in the aggregates. Analogous to the dynamic equilibrium of evaporating and condensing molecules above the surface of water so there is within the liquid a dynamic equilibrium between monohydrol, dihydrol and trihydrol; e. g.,

$$6H_2O \rightleftharpoons 3(H_2O)_2 \rightleftharpoons 2(H_2O)_3$$

The reactions from left to right are exothermic and are favored by lowering of temperature. When the temperature rises the molecules become so active in their movement that the aggregates are broken up.

The Arrangement of the Atoms in Ice.—It has recently been shown by Bragg[4] that in the ordinary ice crystal arrangement of atoms each oxygen is surrounded by four hydrogens at the corners of tetrahedra and that each hydrogen is situated between two oxygens, joining them together (figure 7). In this manner all the stray fields of force of water are satisfied and the change from dihydrol to ice should be exothermic; the latent heat of freezing of the water is 80 calories per gram. The ice lattice is not as compact as dihydrol so that there is an expansion when this re-arrangement occurs. Similarly the increase in volume below 4° is caused by an ever increasing shift of dihydrol into the larger ice molecules or state of aggregation.

The specific heat curve for water sheds some light on the equilibrium between dihydrol and trihydrol with respect to the temperature. The extra heat required to shift the equilibrium gives water a high specific heat at 0° and with ever decreasing ice dissolved in the water the specific heat decreases to a minimum at about 22°. Beyond this point the curve rises again as is the general rule for all substances. But here

[3] Symposium on Water. Trans. Faraday Soc., *6*, 71-123 (1910). The proposal is made there that the water molecules are coupled together directly through the oxygens.

[4] Bragg. Proc. Phys. Soc. (London), *34*, 98 (1922).

there is a steeper rise than is customary aided by the ever increasing amount of heat required to transform the dihydrol into monohydrol, or dissolved steam. Steam, also, has an abnormal specific heat curve. Over the range 250-300° it increases with the temperature as all gases do. Below this range the curve rapidly becomes nearly horizontal at a specific heat of about 0.5. The reason for this is because of the extra amount of heat energy required to overcome the intermolecular attraction, which is abnormally high in proportion to its molecular weight, because of the polar nature of the molecule.

From the compressibility curve (figure 1) some information about the molecular aggregation of water may be obtained. Since the compressibility of any substance decreases with its compression or density that region of minimum compressibility of water corresponds to a preponderance of denser aggregates, which would be dihydrol in this

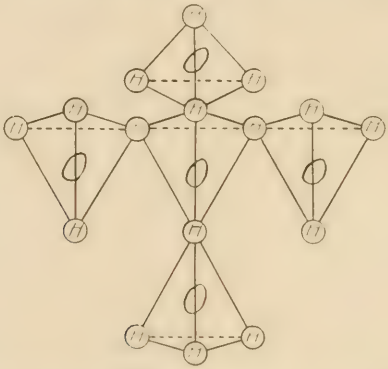

Fig. 7. The ice crystal consists of tetrahedral oxygen atoms surrounded each by four hydrogens. Each hydrogen is between two oxygens. There is no residual polarity. This arrangement is responsible for the hexagonal shape of snow crystals; cf. *National Geographic Magazine*, January, 1923.

case. The compressibility curve reaches a minimum at about 45°, and gives us, probably the best guide as to the relative proportions of these three kinds of aggregates in liquid water. The molecular weight of water dissolved in other solvents approximates 36 which gives us another reason for speaking of water as chiefly dihydrol.

The high latent heat of vaporization is required to complete the change of the compact complex molecule, dihydrol, into monohydrol as well as to separate the monohydrol molecules from each other and to do the work of expansion against the atmosphere. According to our method of reasoning ammonia should also have a high latent heat of vaporization, as it does. This property, together with its high specific heat has a great deal to do with the value of ammonia as a refrigerating agent. The magnitude of their values is caused, in large part, by the polarity of the ammonia molecule.

As a *solvent*, water is extremely important. Bring it into contact with a crystal of ordinary salt and, according to the orthodox method of expressing what happens, the salt dissolves and *then* breaks up into

ions. But the study of crystal structures by X-rays shows that the sodium and chlorine atoms in the crystal lattice are already polarized. The mechanism of solution involves the attraction of the polar water to the surface of the salt molecules. The positive part being attracted to the chloride ions and the negative part to the sodium ions. Other water molecules shove in between the ions and separate them. This separation, of course, requires energy which is made up in part from the heat of the hydration of the ions and in part from the surroundings as is evidenced by the cooling of the water as it dissolves the salt. With some substances, on dissolving, the heat of hydration exceeds that required to separate the ions. The strong acids and bases and several salts like anhydrous sodium and calcium sulfates all go into solution exothermically. Each ion is surrounded with an envelope of hydrated water which aids in holding them apart. This, it seems, is the real cause of the power of water as an ionizing substance rather than its high dielectric constant (specific inductive capacity).

The *dielectric constant* according to the conception of Faraday and Maxwell[5] is due to the presence of dipoles in the medium which are orientated in an electric field. Other substances of high dielectric constant such as formic acid or hydrocyanic acid should, according to the older idea, cause marked ionization of dissolved water; but experiments of P. Walden[6] proved that this is not the case. If the dielectric constant of a material depends upon Faraday's dipoles and if secondary valence combination depends upon polarity there should be a very close parallelism. It is one of the peculiarities of water that there exists a discrepancy in this respect. It seems to indicate that water possesses an exceptionally marked tendency to enter into those hydration reactions which are really physico-chemical; and this is just the point! This type of reactions is controlled, not merely by the attraction of unlike poles in different molecules, but also by the specific chemical character of the molecules themselves. Now the chemical character of the water molecule is such that it seems to bring about the greatest number of hydration reactions. This is to be connected with the small size of the water molecule in which the hydrogens occupy but a small fraction, as well as to the two pairs of extra electrons of the oxygen. This specificity of character is, I believe, confirmed by the remarkable effect on colloidal systems of the ions formed from water, namely, the hydrogen and hydroxyl ions. Jacques Loeb[7] has emphasized the importance of their relative concentrations (pH) in all colloidal work.

According to the ideas here expressed solubility is sometimes a matter of secondary valence combination.[8] It is for water, I feel sure, but there are many other solutions which do not exhibit any evidence of secondary valence combination. If two vessels containing different

[5] Jeans, Electricity and Magnetism, 4th ed., pp. 126-135 (1920).

[6] Cit. 3, p. 71-123.

[7] Loeb. Proteins and Theory of Colloidal Behavior (1922). Science, *56*, 731 (1922).

[8] Secondary valence combination is due to the extra electrons in the oxygen, nitrogen or other atoms. Hydration is a typical example. When a molecule of dissolved substance is hydrated in water solution a rather indefinite envelope of water surrounds the molecule. In solid hydrated crystals a stochiometrical amount of water is in secondary valence combination.

gases are connected there is a diffusion of the gases into each other which, unless the gases are appreciably polar like $HCl+NH_3$, is of the mixture type of solution. Here the laws of mixtures hold. In the same way, when a gas dissolves in a liquid, if the gas is not appreciably polar, Henry's law is obeyed. Non-polar organic liquids like the paraffins, or benzene and its homologs, have very little tendency toward secondary valence combination. The attraction of the molecules for each other is analogous to gravity and is proportional to their molecular weights. Indeed since the mutual attraction of two bodies is inversely proportional to the *square* of the distance between them gravity alone may well be sufficient, when they are touching, to hold the heavier molecules together. If these are the only forces acting, the laws of mixtures should hold. Thus we find that the vapor pressures of solutions of benzene and toluene may be exactly predicted from the concentration. Where there is a polarity effect superimposed, deviations from these simple laws are to be expected.

In the polar solvent, water, the lower alcohols, the lower organic acids, polyhydric alcohols and the sugars are found to be extremely soluble. These compounds have sufficient polarity to bring about the secondary valence type of solution. But when we come to the higher alcohols or acids, the ethers and similar compounds which do contain a polar oxygen, but which have so many nonpolar carbons that the polarity of the oxygen is greatly diminished, the solubility varies with the likeness in degree of polarity.[9] This gives a valuable method for the prediction of solubilities.

The properties of many organic substances can be largely predicted from the principles laid down here. In general, nitrogen and oxygen in organic compounds are the seats of most reactions. The reason for this is chiefly because of their polarity, modified by the extent and arrangement of the carbons. The halogens, sulfur, phosphorus, etc., have similar properties to a lesser extent. Some work has been done on explaining organic reactions according to the octet theory by Langmuir, Stieglitz, Huggins and others,[10] but only a start has been made. It is hoped to make a study of certain organic reactions along the line of the above reasoning.

SUMMARY.

A plausible explanation of the physical and chemical properties of water has been made by an extension of the Lewis-Langmuir theory of atomic structure.

[9] The more nearly alike two substances are in their degree of polarity the greater the tendency to form miscible solutions. Substances widely separated in degree of polarity have very slight if any mutual solubility. The lower alcohols and organic acids are completely miscible in water; ether is somewhat soluble while benzene and the saturated hydrocarbons are so very non-polar that they are practically insoluble in water.

[10] Langmuir. J. Am. Chem. Soc., *42*, 274 (1920). Stieglitz. ibid., *44*, 1293 (1922). Huggins. ibid., *44*, 1607 (1922). Crocker. ibid., *44*, 1618 (1922). Conant. ibid., *43*, 1705 (1921).

Water possesses properties which are different from other liquids. Some of these are:

(1) The large density relative to its molecular weight and the way in which it changes with the temperature.

(2) The change in compressibility with temperature.

(3) The high specific heat and its change with temperature.

(4) A very large latent heat of vaporization.

(5) The magnitude of its dielectric constant.

(6) Solvent power.

(7) Remarkable tendency toward secondary valence combination or hydration.

(8) Notable ionizing power.

Liquid water is largely composed of dihydrol in which may be dissolved some steam molecules or monohydrol and some ice molecules, sometimes called trihydrol. Equilibria between these three kinds of molecular arrangement occurs, so that the variation in the physical properties of water with the temperature is explained.

Oxygen imparts a polarity to the water molecule which causes it to unite into the remarkably compact dihydrol. The polarity is largely responsible for the secondary chemical reactions, the high dielectric constant as well as the solvent and ionizing powers.

In addition to the polarity there are certain specific characteristics of water of a chemical character that have a notable effect on its secondary valence or *physico-chemical* reactivity.

The structures of methane, ammonia and hydrofluoric acid are given according to the Lewis theory and the explanation of their chemical and physical properties is suggested.

The application of these ideas to organic chemistry is indicated.

FAMILIARIZING CHEMISTRY STUDENTS WITH THE GRAM-MOLECULAR VOLUME OF GASES.

W. M. BLANCHARD, DePauw University.

Most teachers of general chemistry have doubtless found students slow in grasping the full significance of molecular weights and gram-molecular volume. Since we arrive at approximate atomic weights through molecular weights, in the case of most elements at least, and since the application of the law of combining volumes necessitates a real familiarity with the volume of the gram-molecule, it is important that students become familiar with molecular weights, not merely as they are represented by a formula so readily written by the instructor, but by actual determination of the molecular weights of the more common elements or compounds as they are presented in the class or lecture room.

The ordinary method used is to evacuate a small glass balloon and then fill it with the gas under consideration. From the weight of the empty balloon, the weight filled with the gas, and the capacity of the balloon, the density of the gas compared with hydrogen is obtained and this value doubled gives the molecular weight.

A balloon flask cannot be used conveniently as indicated unless an automatic generator is being used for producing the gas, or unless the gas is stored under very moderate pressure, as in an ordinary gasometer.

The author has found a satisfactory solution of the problem by employing a light weight gas pipette having a capacity of approximately 500 cc and fitted at each end with a glass stopcock. For more accurate weighing a similar pipette but without the stopcocks is used as a tare. A lecture balance weighing to a centigram or a little less will give results sufficiently accurate for the purpose.

Previous to any determinations of molecular weights in class, the instructor will have determined the capacity of the pipette and its weight when evacuated. In the lecture room the pipette is simply introduced into the stream of gas being prepared for illustrative purposes. Hydrogen, oxygen, chlorine, hydrogen chloride, nitrogen, carbon dioxide, etc., fills the pipette as it flows from the generating vessel on its way to the pneumatic trough or receiving jars, the gas being dried if a little greater accuracy is desired. The pipette is supported in an upright position by a suitable clamp and the gas is introduced at the top when lighter than air, at the bottom when heavier. By the time the instructor has collected all the gas necessary for his lecture demonstrations, the air in the pipette will have been completely replaced by the gas under investigation. The stopcocks are closed, the pipette removed from the system and weighed. Only one weighing being necessary, little time is consumed for the entire operation. From a wall chart prepared for the purpose, the factor for reducing volume to

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

standard conditions is obtained and in a minute or two the student has the weight of 22.4 liters of the gas under standard conditions. After a few such demonstrations he soon learns that the chemical formula is obtained from a determination of molecular weight and not the molecular weight by merely writing down a formula.

A STUDY OF LOCOMOTIVE WHISTLES.

ARTHUR L. FOLEY, Indiana University.

Some two years ago the writer was employed by a railroad company to make a study of the whistle, bell and headlight of one of the company's locomotives that had killed a score of children in a school hack at a road crossing. The driver had stopped, looked, and listened. Apparently he had not seen or heard. Why?

It is not my intention to try to answer the question why in this paper. It *is* my purpose, however, to call attention to several ways in which my experiments indicate that the efficiency of locomotive whistles may be, and should be, improved.

In the first place, the location of the whistle is bad, usually about as bad as could be found unless it were placed inside the cab or underneath the locomotive. It is always placed behind the smoke stack, usually behind one or more domes and the bell, and frequently immediately behind or at the side of pop-off valves, or other accessories mounted on the top of the boiler. All of us know that if we wish to shout to some one at a considerable distance that we turn toward the listener so that the sound will be projected initially in that direction. All of us know that we can be heard at a greater distance if we do not stand behind a lamp post or a tree when we shout. All of us know that the roar of an aeroplane engine as it passes over us comes and goes, sometimes being very loud and sometimes barely audible, and that the variation in the sound intensity is due to the varying air currents and temperature strata through which the sound must pass to reach the ear. Notwithstanding all this, we continue to locate locomotive whistles from the standpoint of convenience only, with no thought of a possible connection between the whistle's location and its efficiency in doing the only thing it is expected to do—to make as much noise as possible along the track ahead of the locomotive, and as little as possible in directions where it is not only not needed but is usually a nuisance.

When the whistle is placed behind the smoke stack, dome, etc., all these objects reflect the energy of the portion of the sound wave that falls upon them. Since a sound wave is long compared to a light wave, the sound shadows thus produced are not comparable in density or definiteness to the light shadows that would result were the whistle replaced by the head light. Nevertheless, there are sound shadows of more or less intensity, depending on the size of the object casting them and on its distance from the sound source; in other words, depending on the solid angle of the object as seen from the sound source. Where the distance is small and the angle large, as when a whistle is mounted very near a dome or an escape valve—(immediately behind or at one side in some recent practice) the intensity of the sound ahead of the locomotive is decreased and at the side or rear increased over what it would be were the whistle mounted in front of the smoke stack.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

That this effect is not of negligible import is proven by the following observations:

In figure 1 the ten points on the broken line curve give the relative intensity of sound as measured with a Rayleigh disk in the ten indicated directions from the whistle or of a locomotive L standing on the track T T. On the first day the observations were attempted a Webster phonometer was used to measure the sound intensity. On account of the extreme sensitiveness of this instrument to small changes of pitch it was not satisfactory for the work in hand. It was therefore with little regret that the writer was forced to discontinue his experiments

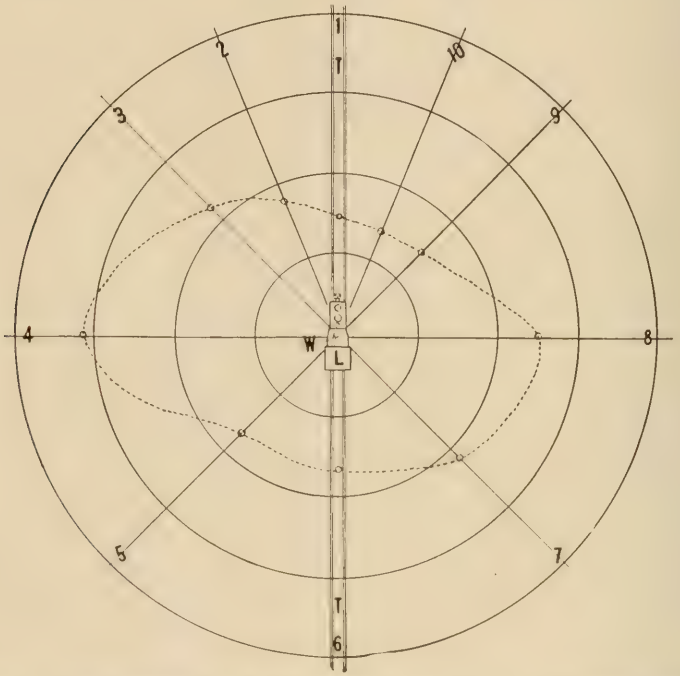

Fig. 1. Sound intensity about a locomotive whistle. 1-10 are the ten points of measurements; L the locomotive; W the location of the whistle; TT the track.

that day on the demand of some one to whom the noise of the whistle was objectionable.

Before undertaking the experiment a second time the writer experimented on different forms of Rayleigh disks. The instrument in the form finally chosen is less sensitive than a tuned Webster phonometer, but has a much wider range through which the pitch of the sound may change without seriously affecting the instrument's sensitivity.

The intensities shown in figure 1 were measured in the ten directions shown, at a uniform distance of 1200 feet from the whistle. Instead of moving the observing station the locomotive was placed on a turn table and the observing station located permanently at the side of the track 1200 feet from the turn table. Then the locomotive was

successively turned so that the relative direction of the observing station was that indicated by the several radii in figure 1.

Even had it been possible to move the Rayleigh disk and adjust it to the same sensitivity in all ten positions, and had the time required been no consideration, the scheme of turning the locomotive had many advantages. It minimized, by making more nearly constant the disturbing effects of winds, temperature changes and differences, the varying topography of the surrounding landscape, and reflections from houses, trees, and other objects.

The curve in figure 1 shows that the intensity of the sound from the whistle at right angles to the track was double the intensity along

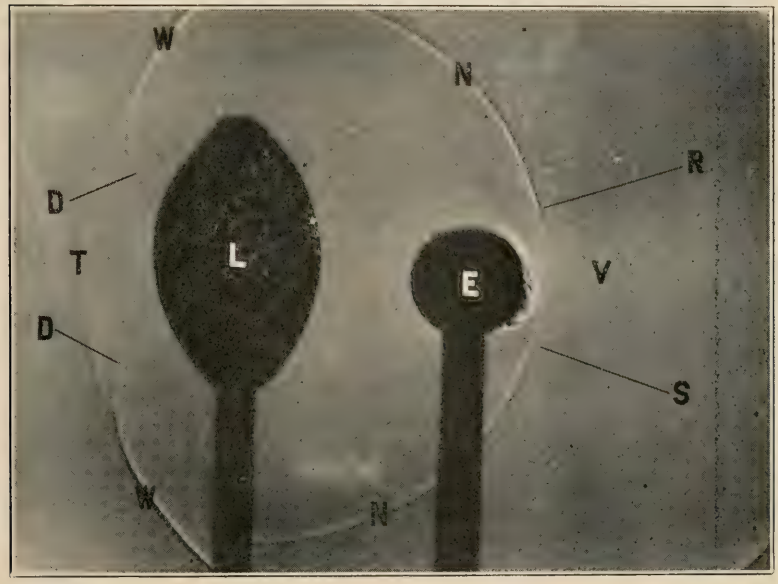

Fig. 2. Sound wave generated by an electric spark, showing reflection, refraction, diffraction and absorption.

the track. The general contour of the curve is about what one should expect from a whistle located as this one was, to the side and rear of, and only four inches from, a steam dome several times as large as the whistle itself. However, the shape of the curve was not determined wholly by reflection. Several other factors contributed to its variation from a circle with the whistle at the center. One of these is that in the case of a whistle located toward the rear of a locomotive boiler the portion of the sound waves that start forward in the direction of the track must pass through the hot air currents arising from the boiler and the hot gases and smoke from the smoke stack. There is consequently more or less energy absorption, reflection and refraction. Indeed, the cylindrical stream of hot gases from the stack is essentially a sound dispersing lens. The sound energy in the shadow of such a

lens is less than it would be were the stream of hot gases replaced by a solid cylinder of the same size.

Figure 2 is a picture of a sound wave generated by an electric spark E between two opaque circular disks. W is a portion of the original wave, N of the wave reflected from the near surface of the lens, and T the wave transmitted by the lens L. D and D are portions of the wave diffracted about the edges of the lens into the geometrical shadow. Note that the conditions are entirely different in the region V, apparently almost a sound void. The hot gases due to the passage of the spark absorb the energy in the region V and refraction by the outer

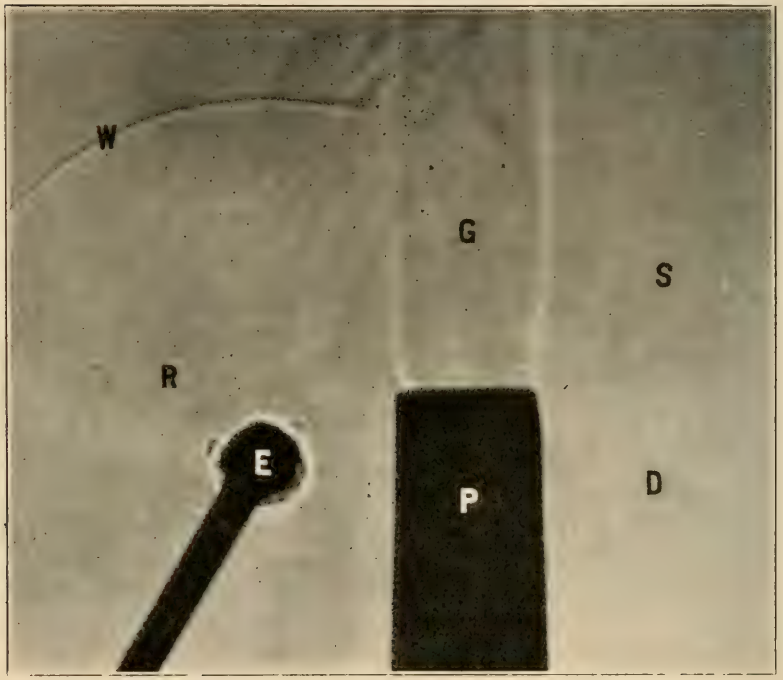

Fig. 3. Sound wave absorption and refraction by a stream of hot gases.

portions of the hot gas region causes the wave to move in the directions R and S, a dispersing effect. Thus normal diffraction into the region V is, to a certain extent, prevented.

In figure 3, G is a stream of hot gases issuing from a vertical cylindrical pipe P, about an inch in diameter and two feet long. The hot gases came from the flame of a Bunsen burner just below the lower end of the pipe. An electric spark E behind the disk produced the sound wave W. R is the wave reflected from the surface of the pipe, D the wave diffracted about the pipe, and S the refracted wave (R and S in figure 2) in advance of the others and therefore undergoing dispersion. When the locomotive is moving rapidly the hot gases form a sort

of blanket over the locomotive which still further absorbs and disperses the sound waves produced by the whistle below.

Another factor which had to do with the sound distribution shown in figure 1 is the design of the whistle itself. The usual cylindrical tube forming the resonator (bell) of a single tone whistle is, in the case of the chime whistle used in this study, divided by longitudinal radial vanes into five compartments or pipes, each of the proper length to give one of the notes of the chime, viz, C, E, G, C′ and C″. T in figure 4 is a transverse section of the whistle and L a longitudinal section, with the omission of the valve mechanism at V. The former shows the relative positions and cross sectional areas of the five pipes while the longitudinal section shows the relative lengths of two of the pipes—C and its octave C′. The fraction of the cylindrical steam jet J used in blowing each of the pipes is shown in the transverse section T, and was 26 per cent in the case of the lower tone C, and respectively 22, 19, 17, and 16 per cent for the other four tones. Thus 60 per cent more energy was used in blowing the lower tone than in blowing the upper tone of this whistle. Since the quality or character of a sound depends on the relative intensity of the several tones which combine to form it, it is evident that the quality of the sound from a chime whistle depends to a degree upon which pipe of the whistle is toward the observer. This variation with direction is accentuated when the whistle is placed very near a steam dome, which interferes more or less with the normal functioning of that part of the whistle which happens to be nearest it. Inasmuch as the Rayleigh disk was not equally sensitive to all five tones of the chime, intensity measurements made with the disk showed considerable variation whenever there was a change in the orientation of the whistle with respect to the dome.

The writer would locate a locomotive whistle in front of the locomotive where it would be free from the several disturbing factors named. He would place it in a reflector of such design as to give a maximum of sound intensity ahead of the locomotive and of such size as to serve as a resonator and thus increase the intensity of the sound at the source.

In advocating the use of a reflector to direct the sound of the whistle along the track the writer has continually met with the argument that such a device would be practically useless on account of the fact that the reflector could not be made large compared to the length of the sound waves to be reflected. This limitation does, of course, affect profoundly the rate at which sound wave energy spreads out after the waves are outside the reflector. But it does not change the action of the reflector itself. The energy of the reflected portion of the sound wave can be headed in the right direction, and much of it will continue in the right direction to reinforce the wave originally projected in that direction. In proof of this assertion it is sufficient to call attention to the effectiveness of a megaphone as a sound director. We should expect a relatively greater directive action from a reflector placed about a whistle. In the case of the voice the waves are originally projected in one hemisphere only, the whistle starts them in both hemispheres. The whistle reflector reflects a portion of the waves in the

one hemisphere, as does the megaphone; but in addition it turns back those that start in the other hemisphere.

To determine whether or not a reflector of moderate size could be made to exert any considerable directive force on the sound from a locomotive whistle, the chime whistle previously described in this paper was placed in a parabolic reflector, as shown in cross section in figure 4, in which all dimensions are to the same scale. The whistle was 6.5 inches in diameter and the aperture of the reflector 28 inches. The reflector was made of plaster paris P cast in a wooden box B. Wooden strips S were nailed in the box in the manner indicated in the drawing to economize on plaster and lessen the weight. The box was mounted on

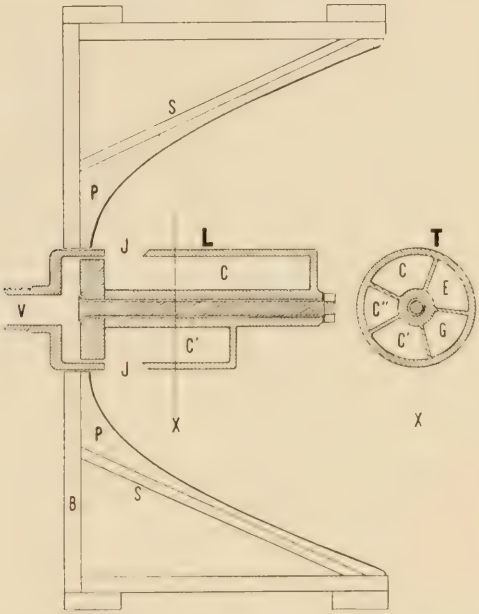

Fig. 4. Transverse section of a locomotive chime whistle, and a longitudinal section of whistle mounted in a modified parabolic reflector. See text for explanation.

castors so that it could be turned on a platform about six feet in diameter and eight feet high. The steam line projected vertically through a hole in the center of the platform and was connected with a union joint to the valve end V of the whistle. This permitted the reflector and whistle to be rotated so that their common axis was in any desired horizontal direction.

The shape of the plaster paris surface of the reflector was obtained as follows: with a focal point on one edge of a board and the edge the axis of a parabola, a curve was drawn on the board and the half parabola sawed out. With the board radial and its straight edge held against the whistle the board was moved around the whistle and the soft plaster paris "wiped" into position. The focus of such a reflector,

if the term focus is permissible, is therefore a circle, and not a point. The focus of any particular portion of the parabolic surface is the nearest point on the focal circle. This focal circle was intended to be coincident with the cylindrical sound source—the cylindrical steam jet, at J, J. The length of the steam jet (the distance from the opening to the lip) was two inches. There is a question as to what portion of the jet should be used, or whether some point beyond the lip should be used, as a focal point in adjusting the whistle in the reflector. Experiments were made with the whistle in one position only, quite likely

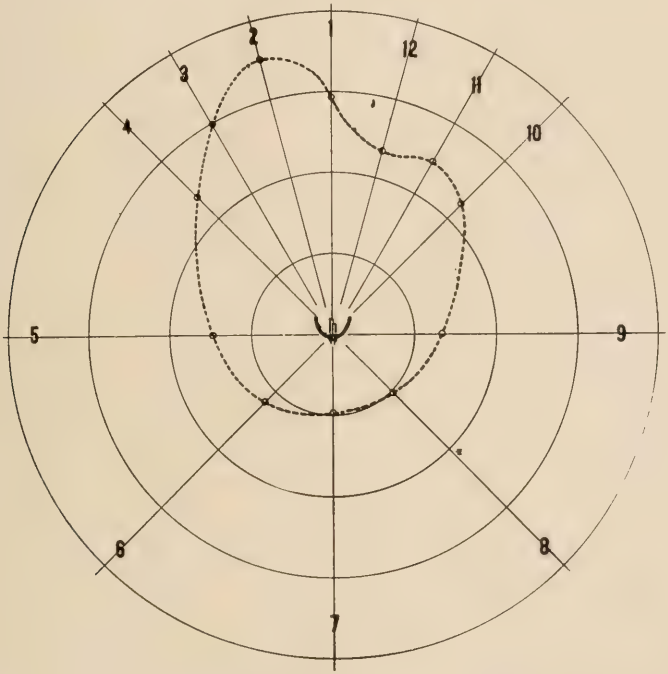

Fig. 5. Sound intensity about a locomotive whistle mounted in a modified parabolic reflector.

not the position to give the reflector the highest possible efficiency. Nevertheless, the action of the reflector was quite marked.

The curve in figure 5 gives the relative intensity of the sound in the 12 directions indicated by the radial lines. The dissymmetry of the curve with respect to the axis in direction 1 is doubtless due to the fact shown in the figure that the whistle was so placed in the reflector that the lower pitched and louder tone was produced on the side of the axis toward direction 2, while the higher and less intense tone was produced on the other side of the axis, in direction 12. Notwithstanding this dissymmetry the curve clearly shows a sound intensity in the direction of the axis of the reflector double that at right angles to the axis and three times that to the rear.

Comparing the result shown in figure 5 with that shown in figure 1, it is seen that, by placing a locomotive whistle in a reflector in front of the smoke stack the intensity of sound along the track in front of the locomotive was increased to four times its value when the whistle was located in the position (W) shown in figure 1. In direction 2 the intensity was five times as great. At the same time the intensity at right angles to the locomotive was correspondingly decreased. The maximum intensity could have been changed from direction 2 to 1 by rotating the whistle in the reflector. No doubt the multiplying factor could be further increased by using a single tone whistle instead of a chime whistle, and by making the reflecting surface of a material having a higher reflection coefficient than plaster paris. In fact, the writer has made the experiment and will publish his results in a later paper, along with the results of his experiments on other phases of the whistle problem.

The placing of a locomotive whistle inside a reflector with its longitudinal axis parallel to the axis of the reflector has advantages other than those already noted. One is, that all parts of the circular steam jet function, which is not the case when the whistle is mounted vertically and the locomotive is running at high speed. This point was investigated by placing a locomotive whistle in a stream of air from a compressor capable of delivering 4,000 cubic feet of air per minute at a pressure of 100 pounds to the square inch. The stream of air was adjusted to give air velocity at the whistle of 20, 40, and 60 miles per hour. Very little effect was noticed at 20 miles per hour. At 40 miles per hour the front portion of the whistle (the part against which the air current was directed) functioned rather poorly, the volume of the sound being considerably less than at 20 miles per hour. At 60 miles per hour it did not function at all, nothing but the hissing sound of escaping steam coming from this portion of the whistle. As the whistle was rotated the character or quality of the sound changed noticeably as one after another of the several tones of the chime was silenced. The steam jet whose vibrations about the lip of the whistle produce the sound, must strike that lip in a particular way to give the best result. When a locomotive is running at high speed the head on pressure and the air currents about the sides of the whistle deflect the steam jet so that some portions of it function poorly and others not at all. When the whistle is inside a reflector the body of air about it is carried along with it and the pressure is uniform on all sides of the jet. This permits it to function normally at all speeds.

All the information the writer has been able to get from psychologists and others is to the effect that the average human ear is more sensitive to sounds of from 1,000 to 1,200 vibrations per second than to those of lower frequency. It would appear, therefore, that most locomotive whistles are from one to two octaves too low in pitch. Raising the pitch would mean smaller whistles, smaller reflectors, less steam consumption, and slightly less diffraction loss.

It would seem that the cost of whistle blowing is an item that has been given little attention. A little consideration will convince one that we "pay dearly for the whistle".

According to the company that manufactured it, the chime whistle used in this investigation—a regular locomotive whistle—requires about 8,352 pounds of steam per hour when blown at 200 pounds steam pressure. Locomotive manufacturers say that seven pounds of steam per pound of coal is good average locomotive practice. This means a coal consumption of 1,190 pounds of coal per hour, more than 18 pounds per minute, approximately one pound of coal for every three seconds, or two pounds for every time the whistle is blown—the series of blasts for any signal aggregating, on the average, about six seconds.

Observations are still in progress on the question of the fraction of the time the whistles are blown. Considerable variation has been found for different engine crews and different railway lines. So far the average runs about two minutes per hour. Assuming this figure, a locomotive equipped with such a whistle and operating it at the indicated pressure requires some 36 pounds of coal and 140 pounds of water per hour for whistling purposes only.

There are in the United States, on Class A railroads alone, some 65,000 locomotives. Investigation is still in progress as to the actual number in service at any one time. It is certain, however, that the cost of blowing locomotive whistles runs into the millions per year and that a considerable saving would be effected if a smaller whistle could be substituted without sacrificing anything from the standpoint of the efficiency of the sound as a warning signal. The experiments herein described warrant the conclusion that this change can be made and the whistle's signalling efficiency increased at the same time.

It is a matter of common observation that locomotive whistles on different roads, and frequently on the same road, differ greatly in pitch and in quality. When one hears a whistle, frequently he can not tell whether it is a locomotive whistle or a factory whistle. He becomes so accustomed to hearing such sounds that they may call forth no mental reaction whatever. If all locomotive and traction car whistles were of one pitch and others were prohibited from using whistles of that or near that pitch, the human ear would soon come to recognize that tone and instinctively associate it with danger. Not only this, but the volume of sound required to produce a mental stimulus would be greatly lessened. The writer advocates a legal standard pitch for all locomotives and traction car whistles, and legislation that will guarantee railway companies its exclusive use.

Waterman Institute for Research,
Indiana University.

THE POWER REQUIRED TO DRIVE SPOKE AND DISK WHEELS AND PULLEYS.

ARTHUR L. FOLEY and B. EISENHOUR.

Some years ago the senior author of this paper, while working on a problem requiring a high peripheral velocity of a wheel or disk, found that the power required to drive a wire spoke bicycle wheel increased with surprising rapidity with increase in rotational speed. He found it impossible with the power at his command to drive a bicycle wheel at the desired speed. A steel disk (a circular saw disk) was readily driven at a much higher speed. This suggested a study of the comparative power required to drive spoke and disk wheels and pulleys.

An automobile axle was removed from its housing and mounted

TABLE I.—POWER REQUIRED TO DRIVE SPOKE AND DISK AUTOMOBILE WHEELS

Revolutions per minute	Miles per hour	Disk Wheel Watts	Spoke Wheel Watts	Difference Watts	Difference H. P. 4 wheels
400	39	300	330	30	0.16
600	58	370	430	60	0.32
800	78	456	572	106	0.57
1,000	98	540	740	160	0.86
1,200	118	720	950	250	1.34
1,400	137	890	1,280	390	2.09
1,600	157	1,190	1,760	570	3.06
1,800	176	1,500	2,390	890	4.77

to run in two plane bearings mounted on a massive wooden framework to minimize vibration. The axle was driven by means of a variable speed motor of the type in which the armature is movable longitudinally in the field, thus giving *any* desired speed between wide limits. The axle speed was determined by means of a Van Sicklen tachometer, and for convenience in calculation was adjusted in each case to multiples of 100 r.p.m. The shaft was carefully lined up in the bearings and was driven at high speed for several days before any observations were taken. Spoke and disk wheels carrying 32″x3″ tires were alternately mounted on the axle and rotated at the speeds indicated in the table. The power required to drive the axle was computed from the terminal voltage and the line current. This, of course, neglects the power lost in the motor itself. However, the study was intended to be comparative only.

Neither of the two automobile wheels was balanced well enough to permit of very high rotational speeds without dangerous vibration.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

After mounting on the axle each was carefully balanced on horizontal knife edges, the spoke wheel requiring much more adjustment than the disk wheel. Even after being adjusted with considerable care, two or three accidents occurred. One was due to the fact that after inflating the tire (to 40 pounds in each case) the writers forgot to put on the valve cap. At a speed near the maximum shown in the table the centrifugal force on the valve plunger opened the valve and permitted the air to escape from the tire. The wheel then threw the tire which, after rebounding from a concrete wall, struck and demolished a twenty-four inch iron pulley on a line shaft.

Several observations were made at each speed shown in table I, and at numerous speeds not recorded. The results given in the table are sufficient to enable us to plot the curves D and S in figure 1, from which the power required for other speeds can be easily determined. D is the power curve for the disk wheel and S for the spoke wheel.

Column 2 of the table gives the speed in miles per hour corresponding to the r.p.m. of the first column, and the last column gives for each speed the extra horse power required to drive four spoke wheels over that required to drive four disk wheels of the same size.

The writers realize that the air friction losses in the case of a wheel rotating on a stationary axis can not be assumed equal to the losses where the axis too is moving. In the case of the stationary axis a body of air about the wheel is thrown into rotary motion, with the result that the air friction loss is less than if the air were at rest. Anything that tends to prevent the air from acquiring this rotary motion increases the air friction losses. When a spoke wheel was rotated inside a wooden box with the sides of the box within a few inches of the wheel, the driving power required to produce a given rotational speed was greatly increased and the temperature of the air in the box rose rapidly. Certainly the air friction losses shown in the last column of table I are not greater than would occur in the case of a spoke wheel automobile moving at the speeds indicated in the second column. It would appear then that the disk wheel has little advantage over the ordinary wood spoke wheel at ordinary automobile speeds. But at the speed at which long distance auto races are usually run—ninety to one hundred miles per hour—air friction losses for spoke wheels are about one horse power more than for disk wheels. This loss, by no means negligible, increases rapidly at higher speeds.

The results in the table are for plain spoke wheels such as are used on light cars. The heavier the spokes the greater the air friction losses. For staggered spokes the loss is still greater. It is very much greater for wire wheels.

If one stands near a pulley rotating rapidly he readily perceives the air currents produced, chiefly due to the fact that the spokes or arms of the pulley act like the blades of a fan. In some cases these air currents may be desirable, for ventilation, cooling, or something of the kind. But if they are not useful they are wasteful in that power is required to produce them. They can be greatly reduced by using web, instead of spoke pulleys, or by placing a tightly fitting flat circular disk in each end of the pulley so as to enclose the spokes. In the experiment

which follows the disks were made of a thick and firm cardboard—called "beaver board".

Seven light cast iron pulleys were mounted on a line shaft some twenty feet long. The shaft was driven by the variable speed motor used in the wheel experiment. One of the pulleys was 30x4.5 inches, four were 24x4, one was 20x4, and one 16x4 inches, all having six spokes. The spokes were elliptical, thin and almost flat, a form designed to minimize air resistance. Notwithstanding this fact, the power required to drive the shaft was noticeably lessened when the spokes were covered with beaver board disks.

Table II gives the power required to drive the shaft at speeds between 300 and 800 r.p.m., when all the pulleys were open, spokes or

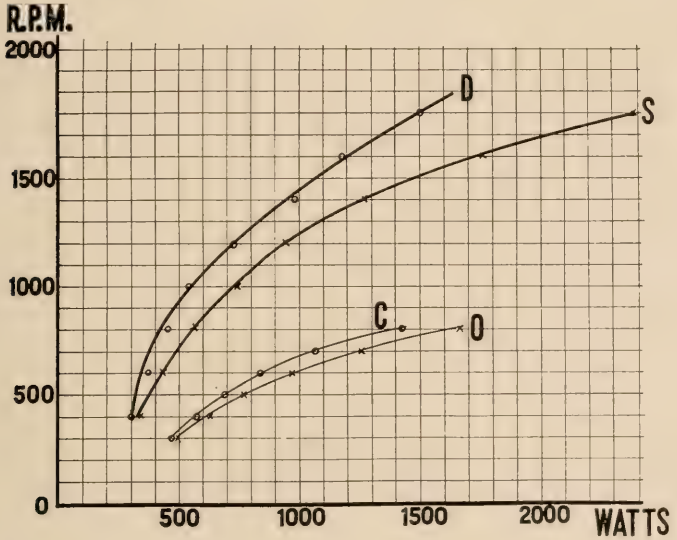

Fig. 1. Results of experiments to determine the power required to drive disk and spoke wheels and pulleys. D, power curve for disk wheel; S, for spoke wheel; C, for pulleys with spokes covered; O, for pulleys with spokes open.

arms exposed—and when all were closed by means of card board disks, spokes enclosed. A plot of some of the results gives the curves O and C of figure 1, the former for open pulleys, the latter for closed pulleys.

The results tabulated are for two cases only—all pulleys open, all closed. Observations were made by measuring the driving power required for all the speeds tabulated—first with all the pulleys closed, then with one open, then two open, and so on to the last series, when all the pulleys were open; that is, all the disks had been removed. The driving power increased slightly every time a pair of the protecting disks was removed.

Inspection of table II and curves O and C shows the web pulley at moderate speeds has little advantage over the spoke pulley of the type used. But at the higher speeds the difference is a matter worth

considering, particularly if a large number of pulleys are in operation. For instance, the seven pulleys in this experiment running at 800 r.p.m. required .32 h.p. less when the spokes were enclosed than when they were exposed. Figuring on the basis of one cent per horse power hour, for ten hours per day and 300 days per year, the saving per year would be $9.60, an average of $1.37 per pulley.

TABLE II.—POWER REQUIRED TO DRIVE SPOKE AND WEB PULLEYS

Speed r. p. m.	All pulleys open	All pulleys closed	Difference in watts	Difference in h. p.
300	490 watts	478 watts	12 watts	0.01
350	560	533	27	0.03
400	625	577	48	0.06
450	700	640	60	0.08
500	775	695	80	0.11
550	870	760	110	0.15
600	980	840	140	0.19
650	1,105	950	165	0.22
700	1,260	1,080	180	0.24
750	1,440	1,135	205	0.27
800	1,660	1,420	240	0.32

In considering the air friction losses of the two types of pulleys, one should note that the spoke pulleys used in the experiment were of the type designed to minimize air friction losses. Heavier and thicker spokes increase the loss, double arm pulleys greatly increase it, and wide flat armed pulleys, such as the usual wood split pulley, very greatly increase it. There is no question as to the economy of enclosing the arms of any wide face and therefore wide armed wood split pulley that is to be operated at high speed. The data of a single experiment will verify this statement.

A wood pulley 12 inches in diameter with flat 6-inch face and having four flat spokes or arms 4.5 inches wide was mounted on an extension of the motor shaft of a standard one-half horse power A.C. motor supported by ball bearing trunions and weighted so as to be in balance in any position. Concentric with the shaft and attached to the motor frame was mounted a grooved pulley five inches in diameter over which a cord passed to a sensitive spring balance, which gave the torque required to hold the motor in a given position against the armature reaction.

When the open pulley was driven at a speed of 1,840 r.p.m. the torque was 3.375 lbs. When the pulley was closed with a cardboard disk at each end and rotated at 1,850 r.p.m., the torque was .25 lb. It will be observed that the torque in the case of the open pulley was more

than thirteen times the torque when the pulley ends were closed. The horse power in each case was as follows:

Open pulley, 1,840 r.p.m. .....0.2463 h.p.
Closed pulley, 1,850 r.p.m. .....0.0183 h.p.
Difference in favor of closed pulley.....0.228 h.p.

Note that the air friction losses in the case of this flat spoke 12x6 wood pulley running at 1,840 r.p.m. were greater than the losses for all seven of the narrow face cast iron pulleys running at 650 r.p.m. This is due in part to the fact that the wood pulley was run at a higher rotational speed. However, the peripheral speed was not much higher than in the case of the cast iron pulleys of larger diameter.

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WHY THE LOGARITHM IN LOGARITHMIC DECREMENT?

R. R. RAMSEY, Indiana University.

When using a ballistic galvanometer it is usual to observe the first deflection and the second deflection and multiply the first deflection by the factor $1 + \frac{1}{2}\lambda$ where λ is the logarithm of the ratio of the first deflection d_1 to second deflection d_2, in order to get the deflection which should have been obtained if the galvanometer were not damped.

If the galvanometer is not damped we have simple harmonic motion. Simple harmonic motion may be considered to be uniform circular motion projected upon a diameter of the circle. In like manner the motion of the galvanometer when damped may be considered to be the projection of the motion of a body moving with uniform angular motion but spiraling in towards the center upon a curve known as the logarithmic spiral.

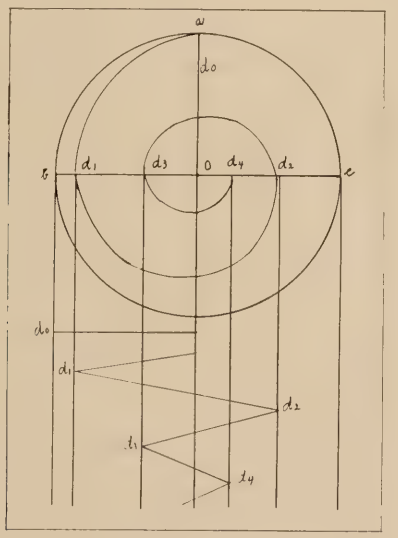

Fig. 1. Projection of logarithmic spiral.

Figure 1 represents a circular of radius d_0 and inside of which is the spiral whose equation is $d = d_0 e^{-\alpha\theta}$; where d is the distance from the center at any point, d_0 is the initial distance at the point, a — in this case d_0 is the radius of the circle also, θ is the angle measured from a and α is a constant.

The first, second, etc., deflections are the horizontal distances from the center o, when $\theta = \pi/2$, $3\pi/2$, etc.

Then since $d = d_0 e^{-\alpha\theta}$

$$d_1 = d_0 e^{-\alpha\pi/2}$$

$$d_2 = d_0 e^{-\alpha 3\pi/2}$$

$$d_3 = d_0 e^{-\alpha 5\pi/2}$$

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

From the above $\frac{d_1}{d_2} = \frac{d_1 e^{-\alpha\pi/2}}{d_0 e^{-\alpha 3\pi/2}} = e^{\alpha\pi}$

$$\frac{d_2}{d_3} = e^{\alpha\pi}$$

$$\frac{d_1}{d_2} = \frac{d_2}{d_3} = \frac{d_3}{d_4} = \ldots = e^{\alpha\pi} = e^{\lambda} = K$$

Where $\lambda = \alpha\pi = \log_e \frac{d_1}{d_2}$.

From equation (1)

$$d_0 = d_1 e^{\alpha\pi/2} = d_1 e^{\lambda/2}$$

since $e^x = 1 + x + x^2/2 + \ldots$

$e^{\lambda/2} = 1 + 1/2\lambda$ if λ is small,

and $d_0 = d_1(1 + 1/2\lambda)$.

This equation is the one usually used in making correction for decrement.

Since $e^{\lambda} = e^{\lambda/2} \times e^{\lambda/2} = K$

$e^{\lambda/2} = \sqrt{K}$

and $d_0 = d_1 \sqrt{K}$

why not multiply by the square root of the ratio instead of by one plus one-half the logarithm of the ratio?

LIST OF INDIANA PLANTS, CHIEFLY FROM PUTNAM COUNTY, COLLECTED 1910-1915 BY EARL J. GRIMES.[1]

EILEEN WHITEHEAD ERLANSON, University of Michigan.

Specimens of the plants listed in this paper are deposited with the Biology Department of DePauw University. The grasses were determined by Agnes Chase, most of the Carices by M. L. Fernald, and the Crataegi by W. W. Eggleston. Many of the other determinations were checked by C. C. Deam. All locations are in Putnam County except as indicated.

I. PTERIDOPHYTA. Ferns and their allies.

POLYPODIACEAE.

Adiantum pedatum L. One mile east of Russellville, on rich wooded hillside, July 10, 1910.

Aspidium marginale (L.) Sw. Raccoon Creek, four miles south of Russellville, on rocky hillside, Aug. 28, 1910.

Aspidium noveboracense (L.) Sw. Raccoon Creek, one mile north of Ferndale, Parke Co., along a stream, Sept. 11, 1910.

Asplenium acrostichoides Sw. Four miles south of Russellville, on rich wooded hillside, Aug. 28, 1920.

Asplenium angustifolium Michx. Five miles south of Russellville, in deep rich woods, Sept. 4, 1910.

Asplenium felix-femina (L.) Bernh. Five miles of Russellville, on rich wooded hillside, Sept. 4, 1910.

Asplenium platyneuron (L.) Oakes. Near Russellville, on dry hillside, Sept. 1, 1910.

Asplenium trichomanes L. Four miles south of Russellville, on dry sandstone ledge, July 10, 1910. Six miles south of Russellville, Sept. 4, 1910. South of Russellville on sandstone cliff, Oct. 5.

Camptosorus rhizophyllus (L.) Link. Sugar Creek at the "Shades" on dry sandsone cliff, Montgomery Co., July 4, 1910.

Cystopteris bulbifera (L.) Bernh. At the "Shades", Montgomery Co., July 4, 1910. Five miles south of Russellville on wooded hillside, July 31, 1910, and in crevasses of rocks, Sept. 4, 1910.

Onoclea sensibilis L. One mile north of Ferndale along roadside, Parke Co., Sept. 11, 1910. Four miles south of Russellville in swamp, Sept. 3, 1910.

Pellaea atropurpurea (L.) Link. At the "Shades" on dry sandstone ledge, Montgomery Co., Sept. 25, 1910.

Phegopteris hexagonoptera (Mich.) Fée. Four miles south of Russellville on dry wooded hillside, Aug. 28, 1910, and Sept. 4, 1910.

Polypodium vulgare L. Three miles south of Russellville, on dry sandstone ledge with Tsuga, July 10, 1910.

[1] Presented at 1922 meeting.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

Polystichum acrostichoides (Mx.) Schott. Four miles south of Russellville on rich bank of Raccoon Creek, June 10, 1910.

Pteris aquilina L. "The Shades" on dry slope, Montgomery Co., July 4, 1910. Madison Township, along right of way of old Big Four R. R.

Woodsia obtusa (Spreng.) Torr. Portland Mills on shaded sandstone cliff, July 4, 1911. Five miles south of Russellville on sandstone ledge, Sept. 4, 1911.

OSMUNDACEAE.

Osmunda claytoniana L. Raccoon Creek south of Russellville on shaded sandstone ledge with Tsuga, July 9, 1911.

Botrychium virginianum (L.) Sw. Four miles south of Russellville in rich woods, June 12, 1910.

OPHIOGLOSSACEAE.

Ophioglossum vulgatum L. Three miles south of Russellville, on dry wooded hillside, June 11, 1911.

MARSILEACEAE.

Marsilea quadrifolia L. In old mill pond south of Vandalia Station, April 30, 1911.

EQUISTACEAE.

Equisetum hyemale L., var. *affine* (Engelm.) A. A. Eaton. "The Shades" at edge of thicket along Indian Creek, Montgomery Co., July 23, 1911. Madison Township near Fern, on right of way of old Big Four R. R., Aug. 8, 1911. Two miles north of Tipton along railroad, Tipton Co., June 9, 1912.

LYCOPODIACEAE.

Lycopodium lucidulum Mx. Four miles south of Russellville on moist sandstone ledge, Aug. 28, 1910.

Lycopodium lucidulum, var. *porophilum* (Lloyd & Underw.) Clute. On moist sandstone cliffs at Fern, Oct. 4, 1911.

SELAGINELLACEAE.

Selaginella apus (L.) Spring. "The Shades" on moist sandstone rock in deep ravine, Montgomery Co., Sept. 25, 1910. Moist sandstone cliff in ravine at Fern, Aug. 8, 1911.

II. SPERMATOPHYTA. Seed Plants.

1. GYMNOSPERMAE.

TAXACEAE.

Taxus canadensis Marsh. Limestone cliff at the "Shades", Montgomery Co., Sept. 25, 1910. On "Devil's Backbone" near Bainbridge, June 25.

PINACEAE.

Juniperus virginiana L. Woods pasture, Russellville, Oct. 2, 1910. Dry hillside at Portland Mills, July 4, 1911.

Larix laricina (DuRoi) Koch. At side of old Lake Manitou, Starke-Marshall county line, Sept. 15, 1915.

Tsuga canadensis (L.) Carr. Four miles south of Russellville, on limestone ledge, July 10, 1910.

2. ANGIOSPERMAE.

TYPHACEAE.

Typha angustifolia L. One mile north of Russellville in small pond, Montgomery Co., July 17, 1910.

SPARGANIACEAE.

Sparganium eurycarpum Engelm. Four miles northwest of Noblesville in muck swamp, Hamilton Co., Aug. 18, 1912.

NAJADACEAE.

Potamogeton americanus C. & S. Three and a half miles south of Russellville, June 11, 1911. Two miles northeast of Bainbridge in Walnut Creek, June 25, 1911.

ALISMACEAE.

Alisma subcordatum L. One mile east of Russellville on edge of pond, Sept. 1, 1910.

Sagittaria latifolia Willd. Raccoon Creek about one mile east of Portland Mills, July 4, 1911.

GRAMINEAE.

Agropyron repens (L.) Beauv. Three miles east of Russellville along right of way of C. H. & D. R. R., June 18, 1911.

Agrostis perennans (Walt.) Tuckerm. Five miles west of Greencastle on open sandstone ledge, Oct. 4, 1911.

Alopecurus pratensis L. Cultivated ground, Lafayette, Tippecanoe Co., May 18, 1914.

Andropogon furcatus Muhl. Washington Township one mile above mouth of Mill Creek, in dry sandy bottom, Aug. 9, 1911. Frequent in Miami silt loam along L. E. & W. R. R. west of Goldsmith, Tipton Co., July 14, 1912.

Andropogon scoparius Mx. Three miles east of Russellville, Sept. 10, 1911.

Andropogon virginicus L. Three miles east of Russellville, Sept. 10, 1911.

Aristida tuberculosa Nutt. Madison Township near Fern along right of way of old Big Four R. R., Aug. 8, 1911.

Bromus secalinus L. North of Tipton, right of way of L. E. & W. R. R., Tipton Co., June 9, 1912. Turkey Run, Parke Co., June 24, 1915.

Bromus tectorum L. Two miles east of Russellville on track of C. H.

& D. R. R., June 18, 1911. North of Tipton, Tipton Co., June 9, 1912.

Cenchrus tribuloides L. One mile east of Russellville, Sept. 3, 1911.

Dactylis glomerata L. Four miles south of Russellville, May 30, 1911.

Danthonia spicata (L.) Beauv. Three and a half miles south of Russellville on dry open hillside, June 11, 1911.

Diarrhena diandra (Michx.) Wood. Five miles south of Russellville in rich wooded ravine, July 9, 1911.

Digitaria sanguinalis (L.) Scop. Cultivated ground, Russellville, Sept. 9, 1911.

Echinochloa crusgalli (L.) Beauv. One mile east of Russellville in a meadow, Sept. 3, 1911. Three miles north of Sheridan in wheat, Hamilton Co., Sept. 8, 1912.

Eleusine indica Gaertn. Cultivated ground, Russellville, Sept. 9, 1911.

Elymus canadensis L. Madison Township near Fern, old Big Four R. R. right of way, Aug, 8, 1911. Along railroad west of Goldsmith, Tipton Co., July 14, 1912.

Elymus striatus Willd. Three and a half miles south of Russellville, June 24, 1911.

Elymus virginicus L. Four miles south of Russellville, sandy alluvial soil along Raccoon Creek, June 6, 1911. One mile east of Portland Mills in sandy alluvial bottom, July 4, 1911. Two miles west of Goldsmith in dry silty loam, Tipton Co., July 14, 1912.

Eragrostis hypnoides (Lam.) BSP. One mile east of Russellville at edge of a pond, Sept. 13, 1911.

Eragrostis megastachya (Koeler) Link. Cultivated ground, Russellville, Sept., 1911.

Eragrostis pectinacea (Mx.) Steud. Madison Township near Fern, along old Big Four R. R., Aug. 8, 1911.

Eragostis pilosa (L.) Beauv. Monroe Township four miles south of Bainbridge, Aug. 14, 1911.

Festuca elatior L. Near Greencastle along old Big Four R. R., June 4, 1911. Three miles east of Russellville on damp bank, June 18, 1911. Two miles west of Bainbridge along roadside, June 25, 1911. One mile east of Petersburg along Dixon's Creek, Tipton Co., June 10, 1912.

Festuca natans Spreng. Near Kempton on right of way of L. E. & W. R. R., Tipton Co., Aug. 18, 1912.

Glyceria nervata (Willd.) Trin. One mile east of Russellville along small stream, June 18, 1911.

Hordeum jubatum L. Street in Russellville, June 6, 1911. Four miles north of Tipton along L. E. & W. R. R., Tipton Co., June 9, 1912.

Hystrix patula Moench. Rocky hillside along Walnut Creek, two miles northeast of Bainbridge, June 25, 1911.

Leersia oryzoides (L.) Sw. Four miles south of Russellville in swampy soil, Sept. 3, 1911.

Lolium multiflorum Lam. Near Russellville, Sept., 1915.

Melica nitens Nutt. Base of wooded slope along roadside at Happy Hollow, northwest of Lafayette, Tippecanoe Co., May 18, 1914.

Muhlenbergia racemosa (Michx.) BSP. Shores of Mud Lake, Starke Co., Aug., 1915.

Muhlenbergia schreberi J. F. Gmel. Three miles south of Russellville on bank of Raccoon Creek, Sept. 3, 1911. In Russellville, Sept., 1911.

Muhlenbergia sobolifera (Muhl.) Trin. Cultivated ground, Russellville, Sept., 1911.

Panicum capillare L. One mile east of Russellville on open hillside. Sept. 3, 1911.

Panicum clandestinum L. Four miles south of Russellville, June 11, 1911.

Panicum dichotomiflorum Michx. Cultivated ground, Russellville, Sept., 1911.

Panicum huachucae Ashe. Three miles south of Russellville on dry open hillside, June 11, 1911.

Panicum virgatum L. Four miles south of Russellville, Sept. 3, 1911. Along L. E. & W. R. R. east of Kempton, Tipton Co., July 14, 1912.

Paspalum stramineum Nash. Madison Township near Fern, Oct. 4, 1911. Four miles east of Russellville, on dry hillside, Sept. 10, 1911. Three miles northeast of Knox in sandhill along C. I. & S. R. R., Starke Co., Aug. 20, 1915.

Phalaris arundinacea L. Along a stream in Russellville, June 24, 1911.

Phleum pratense L. Floating bog at Mud Lake, Starke Co., Sept. 17, 1915.

Phragmites communis Trin. Floating bog at Mud Lake, Starke Co., Sept. 17, 1915.

Poa compressa L. Two miles east of Russellville, June 18, 1911. Four miles north of Tipton along L. E. & W. R. R., June 9, 1912.

Poa pratensis L. One mile east of Russellville, on edge of woods, May 5, 1912.

Poa sylvestris Gray. Five miles south of Russellville on wooded hillside, May 28, 1911.

Setaria glauca (L.) Beauv. Russellville, Sept. 3, 1910.

Setaria viridis (L.) Beauv. Three miles south of Russellville, in dry sandy soil, Sept. 3, 1911.

Spartina michauxiana Hitchc. East of Strawtown in flood plain of White River along a bluff, Hamilton Co., Aug. 31, 1912.

Sphenopholis pallens (Spreng.) Scribn. Five miles south of Russellville on rocky hillside, May 28, 1911. Two miles east of Tipton in low swampy grounds and three miles south of Tipton on edge of low woods, Tipton Co., June, 1912.

Sporobolus asper (Mx.) Kunth. Three miles east of Russellville along railroad, Sept. 10, 1911.

Sporobolus vaginiflorus (Torr.) Wood. Three miles west of Noblesville in clover field, Hampton Co., Sept. 8, 1912. Near Russellville, Aug. 6, 1915.

Stipa spartea Trin. Near Russellville, Aug., 1915.

Tridens flavus (L.) Hitchc. Three miles south of Russellville, in dry sandy soil, July 30, 1911.

CYPERACEAE.

Carex cephalophora Muhl. Four miles south of Russellville in a swamp, June 11, 1911.

Carex cristata Schwein. Four miles south of Russellville in a swamp, June 11, 1911.

Carex davisii Schwein. & Torr. Three miles north of Tipton on edge of woods, low ground, Tipton Co., June 9, 1912.

Carex formosa Dewey. Three miles south of Russellville on dry hillside, June 11, 1911.

Carex frankii Kunth. Four miles east of Russellville in low damp ground along railroad, Sept. 24, 1911.

Carex granularis Muhl. One mile east of Russellville in low wet ground, June 18, 1911.

Carex grayii Carey. One mile east of Russellville in low ground on edge of woods, June 18, 1911.

Carex laxiflora, var. *latifolia* Boott. Five miles south of Russellville in rich woods, May 28, 1911. Three miles north of Tipton in dense white oak woods swamp, Tipton Co., June 9, 1912.

Carex laxiflora, var. *varians* Bailey. Five miles south of Russellville in rich deep woods, May 28, 1911.

Carex lupulina Muhl. One mile east of Russellville in low wet ground, June 18, 1911. Four miles south of Russellville, Sept. 24, 1911.

Carex lurida, var. *gracilis* (Boott) Bailey. Three and a half miles south of Russellville along a small stream, June 11, 1911.

Carex mirabilis Dewey. Along Raccoon Creek five miles south of Russellville, May 28, 1911.

Carex plantaginea Lam. Five miles south of Russellville in rich ravine, April 16, 1911.

Carex rosea Schkuhr. Five miles south of Russellville on dry rocky hillside, May 28, 1911. Three miles north of Tipton in low ground on edge of woods, June 9, 1911.

Carex shortiana Dewey. One mile east of Russellville in low damp ground, June 18, 1911.

Carex squarrosa L. One mile east of Russellville, in low wet ground, June 18, 1911.

Carex stipata Muhl. Four miles south of Russellville in a swamp, June 11, 1911. East of Tipton in low ground along traction lines, Tipton Co., June 9, 1912.

Carex virescens Muhl. Rocky sandstone hillside at Fern, Aug. 8, 1911.

Carex vulpinoidea Michx. Three and a half miles south of Russellville in ravine along stream, June 11, 1911.

Cyperus aristatus Torr. & Hook. Washington Township one mile above mouth of Mill Creek along moist sandy shore, Aug. 9, 1911.

Cyperus diandrus Torr. Near Fern in ditch along Big Four R. R., Oct. 4, 1911.

Cyperus esculentus L. Three miles north of Noblesville on margin of swamp, Hamilton Co., Sept. 8, 1912.

Cyperus strigosus L. Three and a half miles south of Russellville on border of a swamp, July 30, 1911. Four miles east of Russellville

in low wet ground, Sept. 24, 1911. Three miles north of Noblesville on border of swamp, muck and peat soils, Hamilton Co., Sept. 8, 1912.

Eleocharis acicularis (L.) R. & S. One mile east of Raccoon along C. H. & D. R. R. in low damp soil, Sept. 17, 1911.

Eleocharis obtusa (Willd.) Schultes. Half a mile east of Russellville on margin of pond, Sept. 17, 1911.

Eleocharis palustris, var. *glaucescens* (Willd.) Gray. One mile east of Russellville in ditch along railroad, May 21, 1911.

Eriophorum virginicum, var. *album* Gray. Three miles north of Noblesville in muck and peat soil, Hamilton Co., Sept. 8, 1912.

Kyllinga pumila Mx. North of Sheridan in swampy wood, Hamilton Co., Aug., 1912.

Scirpus cyperinus (L.) Kunth. Near Fern along old Big Four R. R. in a ditch, Oct. 4, 1911.

Scirpus lineatus Mx. Along railroad east of Russellville, May 21, 1911. Three miles south of Russellville along a stream, June 11, 1911.

Scirpus polyphyllus Vahl. Near Fern in deep moist ravine, Oct. 4, 1911.

Scirpus validus Vahl. Four miles east of Russellville in a swamp, June 11, 1911.

ARACEAE.

Acorus calamus L. Four miles south of Russellville in low wet ground, May 21, 1911.

Arisaema dracontium (L.) Schott. Three miles south of Russellville on rich wooded hillside, May 22, 1910.

Arisaema triphyllum (L.) Schott. Near Russellville, May, 1910.

Symplocarpus foetidus (L.) Nutt. Three miles south of Russellville in a swamp, April 9, 1911.

LEMNACEAE.

Spirodela polyrhiza (L.) Schleid. Two miles southeast of Cloverdale along Mill Creek, Aug. 13, 1911. Near Limedale in abandoned rock quarry, Oct. 5, 1911.

COMMELINACEAE.

Tradescantia brevicaulis Raf. Dry hillside along Monon railway south of Lafayette, Tippecanoe Co., May 11, 1915.

Tradescantia pilosa Lehm. Four miles south of Russellville on rich wooded hillside, July 10, 1910.

Tradescantia reflexa Raf. Four miles south of Bainbridge on gravel embankment of Monon R. R., Aug. 14, 1911.

JUNCACEAE.

Juncus effusus, var. *solutus* Fernald & Wiegand. Near Limedale in an abandoned rock quarry, Oct. 4, 1911.

Juncus tenuis Willd. South of Russellville, in dry pasture, June 11, 1911. Five miles west of Greencastle in low ground, Oct. 4, 1911. Two miles east of Tipton, low ground along L. E. & W. R. R., Tipton Co., June 9, 1912.

Juncus torreyi Coville. Railway east of Russellville, June 18, 1911.
Luzula campestris (L.) D. C., var. *bulbosa* Wood. Five miles south of Russellville on dry rocky hillside, May 28, 1911.

LILIACEAE.

Allium cernuum Roth. Turkey Run, three miles south of Marshall, dry rocky hillside, July 2, 1911.
Allium tricoccum Ait. Three miles south of Russellville on rich wooded hillside, July 31, 1911.
Asparagus officinalis L. Pasture near Russellville, June 18, 1911.
Camassia esculenta (Ker.) Robinson. Four miles east of Russellville on rich wooded slope, May 1, 1910.
Erythronium albidum Nutt. Near mouth of Ramp Creek south of Russellville, on rich wood hillside, April 9, 1911.
Erythronium americanum Ker. Raccoon Creek four miles south of Russellville on wooded hillside with Trillium, April 16, 1911.
Lilium canadense L. Near Russellville, May 10, 1910.
Lilium superbum L. Three quarters of a mile east of Russellville on right of way of C. H. & D. R. R., July 17, 1910.
Maianthemum canadense Desf. Two miles northeast of Bainbridge along Walnut Creek on dry hillside, June 25, 1911.
Medeola virginica L. Five miles south of Russellville in rich soil on rocky hillside, May 29, 1910.
Polygonatum biflorum (Walt.) Ell. Three miles south of Russellville on rocky wooded hillside, May 8, 1910.
Polygonatum commutatum (R. & S.) Dietr. Four miles east of Russellville on open dry hillside, May 22, 1911.
Smilacina racemosa (L.) Desf. Two miles east of Russellville in shady ravine, May 1, 1911. Four miles south of Russellville in a deep ravine, May 18, 1911.
Smilacina stellata (L.) Desf. Three miles south of Russellville in a swamp, May 7, 1911.
Smilax hispida Muhl. Three and a half miles south of Russellville in a swamp and in flood plain thicket of Raccoon Creek south of Russellville, July, 1911. Four miles east along a stream, Sept. 24, 1911.
Smilax lasioneuron Hook. Northeast of Russellville in a fence-row, June 12, 1911.
Trillium cernuum L. Near Russellville on rocky hillside, April, 1910.
Trillium declinatum (Gray) Gleason. South of Russellville in rich wooded ravines, April and May, 1911.
Trillium grandiflorum (Mx.) Salisb. Three miles south of Russellville on wooded slope along Raccoon Creek, April 30, 1911.
Trillium nivale Riddell. Three miles east of Russellville on moist slope, common, May 1, 1910, March 12, 1911.
Trillium recurvatum Beck. East of Russellville in rich moist woods, April 24, 1910. Four miles south in wooded ravine, May 5, 1911.
Trillium sessile L. East of Russellville in rich woods, April, 1910, and 1911. Five miles south on wooded bank near mouth of Ramp Creek, April 9, 1910.

Uvularia grandiflora Sm. South of Russellville on wooded hillside, along Raccoon Creek, April 30, 1911.

Veratrum woodii Robbins. Four miles south of Russellville on rich wooded hillside, Oct. 9, 1910.

DIOSCOREACEAE.

Dioscorea villosa L. Four miles south of Russellville, rich wooded hillside, June 11, 1911.

AMARYLLIDACEAE.

Hypoxis hirsuta (L.) Coville. North of West Lafayette on dry wooded hillside, Tippecanoe Co., May 18, 1914.

IRIDACEAE.

Belamacanda chinensis (L.) DC. Moist hillside along Sugar Creek near Crawfordsville, Montgomery Co., Aug. 9, 1910. Five miles south of Russellville in dry roadside, Oct. 15, 1911.

Iris versicolor L. Three miles south of Russellville in dry sandy field, June 12, 1910.

Sisyrinchium gramineum Curtis. Raccoon Creek four miles south of Russellville, May 22, 1910.

Sisyrinchium mucronatum Mx. Near Lafayette one mile south of Battle Ground along Monon Railway, Tippecanoe Co., May 22, 1914.

ORCHIDACEAE.

Cypripedium parviflorum Salisb. Five miles south of Russellville on wooded hillside, May 28, 1911.

Epipactis pubescens (Willd.) A. A. Eaton. One mile north of Ferndale on rocky hillside, Parke Co., Sept. 11, 1910.

Habenaria bracteata (Willd.) R. Br. Rich wooded slope at Happy Hollow north of West Lafayette, Tippecanoe Co., June 5, 1914.

Habenaria ciliaris (L.) R. Br. Two miles south of Hamlet in moist sandy soil, Starke Co., July 26, 1915. Five miles east of Knox in undrained sandy flat, Aug. 27, 1915.

Liparis liliifolia (L.) Richard. Five miles south of Russellville in rich dry woods, Sept. 4, 1910. Deep woods along Raccoon Creek, May 20, 1911.

Orchis spectabilis L. Along Raccoon Creek four miles south of Russellville, May 8, 1910.

Pogonia trianthophora (Sw.) BSP. One mile north of Ferndale, rich deep woods, Parke Co., Sept. 11, 1910. Two miles southeast of Carpentersville along Big Walnut Creek in rich level woods, Aug. 17, 1911. One mile north of Cataract along Mill Creek, Owen Co., Aug. 12, 1911.

Spiranthes cernua (L.) Richard. North shore of Bass Lake in fine wet sand among rushes, Starke Co., Sept. 17, 1915. High wooded hill south of Russellville, July, 1915.

Spiranthes gracilis (Bigel.) Beck. Three and a half miles south of Russellville in high dry woods, Sept. 18, 1910.

PIPERACEAE.

Saururus cernuus L. Washington Township along shore of Mill Creek one mile above its mouth, Aug. 10, 1911.

SALICACEAE.

Populus alba L. Four miles south of Bainbridge, Aug. 14, 1911.

Populus candicans Ait. Four miles south of Russellville on open hillside. Introduced. Sept. 3, 1911.

Populus grandidentata Mx. Three miles south of Russellville on dry hillside, July 31, 1910. Near Raccoon on C. H. & D. R. R., Sept., 1911.

Populus deltoides Marsh. Four miles east of Russellville on dry railway bank, May 21, 1911.

Populus tremuloides Mx. Poor dry hillside north of Fern cliffs, Oct. 4, 1911.

Salix alba L. Four miles south of Russellville along Raccoon Creek, 1911.

Salix cordata Muhl. Four miles south of Russellville along bank of Raccoon Creek and east of Russellville, 1911.

Salix discolor Muhl. Four miles south of Russellville in a swamp, 1911. Four miles east of Russellville, Oct., 1911. Five miles west of Greencastle in ditch along old Big Four R. R., 1911.

Salix humilis Marsh. Poor dry hillside north of Fern cliffs, Oct., 1911.

Salix longifolia Muhl. Near Russellville in ditch along roadside, Sept. 20, 1911.

Salix nigra Marsh. Near Russellville on edge of pond, 1911. East of Tipton on edge of pond, Tipton Co., June 9, 1912.

MYRICACEAE.

Myrica asplenifolia L. South shore of Bass Lake, in sandy woods, Starke Co., 1915.

JUGLANDACEAE.

Carya alba (L.) K. Koch. One mile southeast of Kempton on Miami silt knoll with *Quercus alba* and *Q. imbricaria*, Tipton Co., July 16, 1912.

Carya cordiformis (Wang.) K. Koch. Four miles south of Russellville in wooded ravine, Sept. 17, 1911.

Carya glabra (Mill.) Spach. Three miles south of Russellville, wooded hill along Raccoon Creek, Sept. 17, 1911. Open hillside near Fern, Oct. 4, 1911.

Carya laciniosa (Mx. f.) Loud. Four miles south of Russellville on poor hillside, Sept., 1911. One mile north in rich woods, Montgomery Co., 1911.

Carya microcarpa Nutt. Three miles south of Russellville, dry hillside, Sept. 17, 1911.

Carya ovata (Mill.) K. Koch. Three miles south of Russellville, dry hillside, Sept. 17, 1911.

Juglans cinerea L. Four miles south of Russellville on limestone cliffs, May 30, 1911.

Juglans nigra L. Near Russellville, 1911.

BETULACEAE.

Betula pumila L. Seven miles east of Knox, Starke Co., Aug. 25, 1915.
Carpinus caroliniana Walt. Three miles south of Russellville along a stream, Apr. 30, 1911.
Corylus americana Walt. Four miles south of Russellville, July 31, 1910.
Ostrya virginiana (Mill.) K. Koch. Near Russellville, 1911.

FAGACEAE.

Fagus grandifolia Ehrh. Three miles south of Russellville on dry hillside, April 30, 1911.
Quercus alba L. South and east of Russellville in poor soil, 1911.
Quercus bicolor Willd. East of Russellville, Sept. 17, 1911.
Quercus muhlenbergii Englem. South of Russellville on dry hilltop, Sept. 3, 1911. Six miles northwest of Noblesville along Lafayette road on gravelly slope, Hamilton Co., 1912.
Quercus palustris Muench. Near Fern on open hillside, Oct. 4, 1911. East of Russellville in low woods.
Quercus rubra L. Four miles east of Russellville on crest of dry ravine Sept., 1911. Near Fern in thin soil on open hilltop, Oct. 4, 1911.
Quercus velutina Lam. Near Fern, poor soil of open hilltop, Oct., 1911.

URTICACEAE.

Boehmeria cylindrica (L.) Sw. Three miles south of Russellville in a swamp, Aug. 28, 1910.
Cannabis sativa L. Near Portland Mills along roadside, Sept. 11, 1910.
Celtis occidentalis L. Three miles south of Russellville along Raccoon Creek, May 7, 1911.
Humulis lupulus L. South of Russellville on border of deep woods, Aug. 18, 1910.
Laportea canadensis (L.) Gaud. One mile east of Russellville in rich woods, Sept. 1, 1910.
Maclura pomifera (Raf.) Schneider. Along Raccoon Creek south of Russellville, June 19, 1910.
Morus alba L. Five miles south of Russellville along roadside, 1910.
Morus rubra L. Near Russellville in a field, June, 1910.
Parietaria pennsylvanica Muhl. Three miles east of Russellville on rich shaded hillside with Pilea pumila, Sept. 24, 1911.
Pilea pumila (L.) Gray. One mile east of Russellville in wet soil, Sept. 1, 1910.
Ulmus americana L. Three miles east of Russellville near Raccoon Creek, March 12, 1911.
Ulmus fulva Mx. South and east of Russellville in wooded ravines, 1911.
Ulmus racemosa Thomas. Three miles south of Russellville on a limestone ledge, Apr. 23, 1911.

SANTALACEAE.

Comandra umbellata (L.) Nutt. High hilltop at Happy Hollow northwest of Lafayette, Tippecanoe Co., May 18, 1914.

ARISTOLOCHIACEAE.

Aristolochia serpentaria L. Four miles east of Russellville in rich woods, July 24, 1910.

Asarum canadense L. North and south of Russellville in rich woods, Apr., 1910 and 1911.

Asarum canadense, var. *acuminatum* Ashe. Three miles south of Russellville on rich wooded hillside, May 7, 1911.

POLYGONACEAE.

Fagopyron esculentum Moench. Two miles west of Crawfordsville along Big Four R. R., Aug. 10, 1910. Weed in cultivated ground west of Russellville, July, 1912.

Polygonum acre HBK. Near Russellville in open woods, Sept., 1910 and 1911.

Polygonum arifolium L. One mile north of Ferndale in damp woods in ravine, Sept. 11, 1910. Near Fern in deep ravine, Aug. 8, 1911.

Polygonum aviculare L. On track of Monon railroad north of Greencastle, Aug. 27, 1911.

Polygonum convolvulus L. East of Russellville along railroad, July, 1911.

Polygonum hydropiperoides Mx. One mile north of Strawtown on bottoms of Duck Creek, Hamilton Co., Sept. 8, 1912.

Polygonum lapthifolium L. South of Russellville in low damp soil, Aug. and Sept., 1910.

Polygonum muhlenbergii (Meisn.) Wats. Washington Township in swampy bottom near mouth of Mill Creek, Aug. 9, 1911. West of Goldsmith in low ground on Carrington clay loam, Tipton Co., July 14, 1912.

Polygonum orientale L. Crawfordsville, waste ground, Montgomery Co., Aug. 9, 1910. Four miles south of Bainbridge in low ground, Aug. 14, 1910.

Polygonum pennsylvanicum L. Near Russellville on bank of a stream, Sept., 1910. East of Raccoon in damp ground, Sept., 1911.

Polygonum persicaria L. Three miles east of Russellville, low ground, Sept. 24, 1911.

Polygonum sagittatum L. East of Russellville in wet beech woods, Sept. 1, 1910.

Polygonum scandens L. Three miles south of Russellville in damp ground, Aug. 21, 1910.

Polygonum tenue Mx. Dry open hillside north of Fern, Aug. 8, 1911. Three miles northeast of Knox, sandy hill along C. I. & S. R. R., Aug. 20, 1915.

Polygonum virginianum L. Three miles south of Russellville on border of rich woods, Aug. 21, 1910.

Rumex acetosella L. In Russellville cemetery, Aug. 1, 1910. Three miles south, May 19, 1912.

Rumex altissimus Wood. West of Greencastle at crossing of Monon and old Big Four Railroads, on ballasted cinder bank, June 4, 1911.

Rumex crispus L. Near Russellville, Oct. 5, 1911.

Rumex obtusifolius L. Near Russellville along a stream, July 10, 1910.

CHENOPODIACEAE.

Chenopodium album L. Weed in Russellville, Oct. 2, 1910. Near Fincastle along roadside and along Monon R. R., near Roachdale, 1911.

Chenopodium album, var. *viride* (L.) Moq. Weed in Russellville, Sept. 3, 1911.

Chenopodium ambrosioides L. Street in Russellville, Oct. 2, 1910. Five miles north of Sheridan in low wet woods, Hamilton Co., Aug. 14, 1912.

Chenopodium botrys L. Near Crawfordsville in dry sandy soil, Montgomery Co., Aug. 10, 1910.

Chenopodium glaucum L. In Kempton on dry ballast of railroad, Tipton Co., July 14, 1912.

Chenopodium hybridum L. Weed in Russellville, Aug. 16, 1911.

Chenopodium murale L. Three miles north of Waveland along roadside, Montgomery Co., July 23, 1911.

Cycloloma atriplicifolium (Spreng.) Coult. At Fern stop on track of Big Four R. R., Oct. 4, 1911.

Salsola kali, var. *tenuifolia* G. F. Mey. Four miles south of Bainbridge on track of Monon R. R., Aug. 14, 1911.

AMARANTHACEAE.

Acnida tuberculata Moq. Three miles north of Noblesville on border of bog, Hamilton Co., Sept. 8, 1912.

Amaranthus blitoides Wats. Along railroad east of Russellville, Sept. 3, 1911.

Amaranthus graecizans L. One mile east of Russellville along railroad, Sept. 18, 1910.

Amaranthus hybridus L. Cloverdale Township along old bed of Mill Creek, Aug. 13, 1911.

Amaranthus retroflexus L. Weed in Russellville, Sept., 1911. Near Raccoon along creek, Oct. 5, 1911. Waste ground in Greencastle.

Amaranthus spinosus L. In Russellville, Sept., 1910.

PHYTOLACACEAE.

Phytolacca decandra L. North of Russellville in rich fence row, Montgomery Co., July 17, 1910. East of Russellville along railroad July 30, 1911.

NYCTAGINACEAE.

Oxybaphus nyctagineus (Mx.) Sweet. Three miles west of Greencastle on bank of old Big Four R. R., June 4, 1911. East of Portland Mills in sandy alluvial bottom, July 4, 1911.

ILLECEBRACEAE.

Anychia canadensis (L.) BSP. Three miles east of Russellville, July, 1910.

AIZOACEAE.

Mollugo verticillata L. Weed in Russellville, July 25, 1910.

CARYOPHYLLACEAE.

Arenaria patula Mx. Two miles south of Lafayette on dry slope along old canal, May 11, 1914.

Arenaria serpyllifolia L. In a woodlot west of Fafayette, Tippecanoe Co., July 3, 1914. Turkey Run on dry sterile hillside, Parke Co., June 24, 1915.

Cerastium arvense L. Dry hillside one mile north of Russellville, Montgomery Co., July 17, 1910.

Cerastium nutans Raf. Five miles south of Russellville, dry open hillside, May 28, 1911.

Saponaria officinalis L. One mile east of Russellville in sandy soil, July 10, 1910.

Silene antirrhina L. Two miles northeast of Bainbridge in sandy bottom field, June 25, 1911.

Silene noctiflora L. Along right of way of Monon R. R. near Crawfordsville, Montgomery Co., June 15, 1910.

Silene stellata (L.) Ait. f. Four miles east of Russellville on dry wooded hillside, July 24, 1910.

Silene virginica L. Three miles east of Russellville, wooded hillside, May 1. 1910.

Stellaria longifolia Muhl. Three miles south of Russellville in a swamp, June 11, 1911.

Stellaria pubera Mx. East of Russellville in open woods, April, 1910. Four miles south on a sandstone cliff, May 7, 1911.

PORTULACACEAE.

Claytonia virginica L. Five miles south of Russellville in damp shady soil along Raccoon Creek, April 30, 1911. Near Russellville, May, 1909.

NYMPHACACEAE.

Castalia odorata (Ait.) Woodville & Wood. In Greencastle in water of an old quarry, Aug. 27, 1911.

Nymphaea advena Ait. In a pond south of Russellville, July 3, 1911.

RANUNCULACEAE.

Actaea alba (L.) Mill. East of Russellville on rich wooded hill, May 22, 1910. Six miles south in rich ravine, May 18, 1911.

Anemone canadensis L. South of Russellville along Raccoon Creek, June 12, 1910.

Anemone virginiana L. Four miles south of Russellville in thicket at Raccoon Creek, April, 1910.

Anemonella thalictroides (L.) Spach. Five miles south of Russellville, rich shaded ravine in woods, April, 1910. Near mouth of Ramp Creek, April 9, 1911.

Aquilegia canadensis L. Three miles south of Russellville on sandstone bluff, April 17, 1910.

Caltha palustris L. Raccoon Creek south of Russellville, April 16, 1911.

Clematis viorna L. Six miles south of Russellville in deep ravine, Oct. 16, 1910.

Clematis virginiana L. Three miles west of Crawfordsville along roadside, Montgomery Co., Aug. 10, 1910.

Delphinium tricorne Mx. Four miles east of Russellville in rich moist soil of deep ravine, May 1, 1910.

Hydrastis canadensis L. Five miles south of Russellville, in rich low ground in dense woods, July 29, 1910. One mile north of Russellville in deep rich woods.

Isopyron biternatum (Raf.) T. & G. Four miles south of Russellville in deep ravine, April 30, 1911. Near Russellville in woodland pasture, May 15, 1909.

Ranunculus abortivus L. One mile east of Russellville in woods, April 20, 1910.

Ranunculus acris L. Near Crawfordsville along old Big Four R. R., Montgomery Co., June 4, 1911. South shore of Bass Lake, Starke Co., Aug. 21, 1915. Russellville, June, 1911.

Ranunculus circinatus Sibth. Along Raccoon Creek four miles south of Russellville, May 21, 1911. East of Tipton in ditch, Tipton Co., June 9, 1912.

Ranunculus hispidus Mx. North of Russellville in low damp woods, April 24, 1910.

Ranunculus micranthus Nutt. North of Russellville in rich woods, May 30, 1911.

Ranunculus recurvatus Poir. Five miles south of Russellville, in rich sheltered ravine, April 17, 1910.

Ranunculus septentrionalis Poir. Three miles south of Russellville in damp ground near Raccoon Creek, April 30, 1911.

Thalictrum dasycarpum Fisch. & Lall. Four miles south of Russellville in moist soil, June 19, 1910.

Thalictrum dioicum L. Five miles south of Russellville on shaded hillsides near Raccoon Creek, April, 1910.

MAGNOLIACEAE.

Liriodendron tulipifera L. Three miles south of Russellville, on dry open hillsides, May and June, 1911.

ANONACEAE.

Asimina triloba Dunal. Near Russellville in open woods pasture, June 5, 1910. Three miles south in deep ravine, Sept. 17, 1911.

MENISPERMACEAE.

Menispermum canadense L. North of Ferndale in rich soil, Parke Co., Sept. 11, 1910. Three miles south of Russellville in fence row, Oct., 1911.

Berberis vulgaris R. Br. Four miles south of Russellville along small stream in deep ravine, May 22, 1910.

BERBERIDACEAE.

Caulophyllum thalictroides (L.) Mx. Four miles south of Russellville in rich woods, May 7, 1911.

Podophyllum peltatum L. East of Russellville, in rich moist woods, April 24, 1910.

LAURACEAE.

Benzoin aestivale (L.) Nees. East of Russellville in low beech woods, Sept. 11, 1910.

Sassifras variifolium (Salisb.) Ktze. South of Russellville in poor soil, Aug. 31, 1911.

PAPAVERACEAE.

Sanguinaria canadensis L. South of Russellville on rich wooded hillsides, April, 1911.

Stylophorum diphyllum (Mx.) Nutt. South of Russellville, April, 1910, May, 1911.

FUMARIACEAE.

Corydalis sempervirens (L.) Pers. One mile southwest of Round Lake in fence-row in woods, on Dunkirk sand, Starke Co., Aug. 27, 1915.

Dicentra canadensis (Goldie) Walp. Five miles south of Russellville, in deep ravine in woods, April 17, 1910.

Dicentra cucullaria (L.) Bernh. Six miles south of Russellville on limestone cliffs, May 7, 1911. Three miles south, April 20, 1911.

CRUCIFERAE.

Alyssum alyssoides L. West Lafayette, Tippecanoe Co., May 18, 1912.

Arabis dentata T. & G. South of Russellville along Raccoon Creek, sandy soil in thicket, May 22, 1910.

Arabis laevigata (Muhl.) Poir. Five miles south of Russellville on rocky hillside, May 11, 1910. West Lafayette in fill along road, Tippecanoe Co., May 18, 1912.

Brassica arvensis (L.) Ktze. Near Greencastle along old Big Four R. R., June 4, 1911. Three miles east of Russellville on railroad, June 18, 1911.

Brassica nigra L. Two miles south of Russellville along roadside, July 30, 1911.

Camelina microcarpa Andrz. Along right of way of Monon R. R. near Crawfordsville, June 15, 1910.

Camelina sativa (L.) Crantz. In Purdue Orchard, Lafayette, Tippecanoe Co., May 17, 1914.

Cardamine bulbosa (Schreb.) BSP. East of Russellville, boggy soil in thick woods, April 24, 1910. Three miles south in a swamp, May 7, 1911.

Cardamine douglassii (Torr.) Britton. East of Russellville, damp soil in open woods, April 20, 1910. Five miles south beside a spring, April 9, 1911.

Cardamine pennsylvanica Muhl. Five miles south of Russellville in damp ravine, May 29, 1910. In fruit, Aug. 15, 1911. Two miles east of Bainbridge, beside cool spring, in deep woods.

Conringia orientalis (L.) Dumort. Just north of Roachdale along ballasted bank of Monon R. R., Montgomery Co., May 6, 1911. Near Greencastle station on bank of Monon R. R., June 4, 1911.

Dentaria laciniata Muhl. South and east of Russellville in rich moist shaded soil, April, 1911.

Diplotaxis tenuifolia (L.) DC. Two miles north of Roachdale along Monon R. R., Montgomery Co., May 6, 1911.

Erysimum cheiranthoides L. Three miles north of Tipton in wheat, Tipton Co., June 9, 1912. Scarce but noted elsewhere in county.

Erysimum parviflorum Nutt. Near Greencastle on track of Monon R. R., June 4, 1911.

Hesperis matronalis L. Two miles north of Crawfordsville along roadside, Montgomery Co., Aug. 9, 1910.

Iodanthus pinnatifidus (Mx.) Steud. Five miles south of Russellville in sandy soil along Raccoon Creek, June 5, 1910.

Lepidium campestre (L.) R. Br. One mile north of Tipton along railroad, Tipton Co., June 9, 1912.

Radicula nasturtium-aquaticum (L.) Brit. Near Greencastle along Monon R. R., low wet ground, June 4, 1911.

Radicula palustris (L.) Moench. Four miles east of Russellville near a stream, June 19, 1910. Near Greencastle along Monon R. R., June 4, 1911. Near Tipton in wet grounds, Tipton Co., July, 1912.

Radicula palustris, var. *hispida* (Desv.) Rob. Near Goldsmith in ditch along L. E. & W. R. R., Tipton Co., July 14, 1912.

Raphanus sativus L. On track of Monon R. R., south of Roachdale, Oct. 5, 1911.

Sisymbrium altissimum L. Along Monon R. R. near Crawfordsville, Montgomery Co., June 15, 1910; and near Greencastle station, June 4, 1911. Four miles north of Tipton along L. E. & W. R. R., Tipton Co., June 9, 1912.

Sisymbrium canescens Nutt. Along Monon R. R. south of Roachdale, May, 1911.

Sisymbrium incisum Engelm. Along right of way of Monon R. R. south of Lafayette, Tippecanoe Co., May 11, 1915.

Thalaspi arvense L. Along ballasted banks of Monon R. R. north of Roachdale, Montgomery Co., May 6, 1911; and south of Lafayette, Tippecanoe Co., May 22, 1915.

CAPPARIDACEAE.

Polanisia graveolens Raf. Four miles east of Russellville on gravelly bank along railroad, July 24, 1910.

SARRACENIACEAE.

Sarracenia purpurea L. About Mud Lake in a tamarack swamp, Starke Co., Sept. 17, 1915.

CRASSULACEAE.

Penthorum sedoides L. One mile east of Russellville in railroad ditch, July 24, 1910.

Sedum ternatum Mx. Five miles south of Russellville in moist rocky ravine, May 29, 1910.

SAXIFRAGACEAE.

Heuchera americana L. Four miles east of Russellville on dry exposed hillside, May 22, 1910.

Hydrangea arborescens L. Four miles south of Russellville on rocky hillside along Raccoon Creek, July 10, 1910.

Hydrangea cinerea Small. At the "Shades", moist hillside, Montgomery Co., July 23, 1911.

Hydrangea deamii (Small) St. John. Two miles northeast of Bainbridge on a moist shaly hillside near "Devil's Backbone", Aug. 15, 1911.

Mitella diphylla L. Five miles south of Russellville on sandstone cliffs in a ravine, April, 1910 and 1911.

Parnassia caroliniana Mx. Along Tippecanoe River near Round Lake in a muck swamp, Starke Co., Aug. 31, 1915.

Ribes cynosbati L. North and south of Russellville in rich woods, April, 1910 and 1911.

Ribes floridanum L'Her. Four miles south of Russellville in open woods May 18, 1911.

Saxifraga pennsylvanica L. Three miles south of Russellville in a swamp, May 18, 1911.

HAMAMELIDACEAE.

Hamamelis virginiana L. East of Russellville on wooded hillsides, Nov. 6, 1910, and June 18, 1911.

Liquidambar styraciflua L. Two miles southeast of Cloverdale along roadside, Aug. 15, 1911. Single tree.

PLATANACEAE.

Platanus occidentalis L. Three miles south of Russellville on open hillside, May 22, 1911.

ROSACEAE.

Agrimonia parviflora Ait. One mile east of Russellville in low wet grounds, Sept. 1, 1911.

Agrimonia rostellata Wallr. Four miles east of Russellville in rich dense woods, June 24, 1910.

Amelanchier canadensis (L.) Medic. Five miles south of Russellville wooded hillside along Raccoon Creek, Sept. 4, 1910.

Crataegus calpodendron (Ehr.) Medic. East and south of Russellville in rich beech woods, Sept. and Oct., 1911.

Crataegus crus-galli L. Eel River Falls at Cataract on dry sterile bluff, Owens Co., Aug. 12, 1911.

Crataegus mollis (T. & G.) Scheele. North and east of Russellville in beech woods, May and Sept., 1911.

Crataegus prainosa (Wendl.) C. Koch. Four miles south of Russellville on dry wooded hillside, July 30, 1911.

Crataegus punctata Jacq. Collected around Russellville, flowers May, and fruit Sept., 1911.

Crataegus succulenta Schrad. Three miles south of Russellville on wooded hilltop, Sept. 3, 1911.

Filipendula rubra (Hill) Rob. One mile west of Goldsmith in low moist ground, Tipton Co., July 14, 1912. Frequent.

Fragaria vesca, var. *americana* Porter. Five miles south of Russellville on a dry sandstone ledge, May 11, 1910.

Fragaria virginiana, var. *illinoensis* (Prince) Gray. South of Russellville in sandy soil along Raccoon Creek, May 14, 1910.

Geum canadense Jacq. Four miles east of Russellville on border of woods, June 19, 1910.

Geum flavum (Porter) Bick. South of Russellville in rich wooded ravine, July, 1910 and 1911.

Geum macrophyllum Willd. Two miles east of Tipton, moist rich soil along L. E. & W. R. R., June 9, 1912.

Geum vernum (Raf.) T. & G. East of Russellville in moist wood, common, April 20, 1910.

Geum virginianum L. Washington Township one mile above mouth of Mill Creek in low swampy bottom, Aug. 9, 1911.

Physocarpus opulifolius (L.) Maxim. Near Crawfordsville in alluvial soil along Sugar Creek, June 15, 1910.

Potentilla anserina L. West of Tipton in yards of L. E. & W. R. R., June 17, 1912. Several plants seen.

Potentilla argentea L. One mile west of Brems on a dune-like hill, Knox Co., Aug. 24, 1915. Very characteristic.

Potentilla arguta Pursh. Northwest of Pence on state line along roadside in low prairie ground, Warren Co., July 24, 1914.

Potentilla canadensis L. Five miles south of Russellville in dry soil on edge of woods, May 11, 1910.

Potentilla monspeliensis L. Four miles east of Russellville in dry soil along railroad, and south in sandy fields, July, 1910 and 1911.

Potentilla recta L. Five miles southeast of Tipton in an orchard, Tipton Co., June 15, 1915.

Prunus americana Marsh. Three and a half miles south of Russellville on wooded hillside with *Amelanchier canadensis*, April 23, 1911. South portion of Washington Township along roadside, Aug. 17, 1911.

Prunus pumila L. Two miles south of Hamlet in a swamp on Clyde fine sand, Starke Co., July 26, 1915.

Prunus serotina Ehrh. East and south of Russellville in open fields, May, 1910 and 1911.

Prunus virginiana L. Turkey Run, on moist sandstone cliff at the Narrows, Parke Co., July 1, 1911. Washington Township one mile above mouth of Mill Creek, on wooded limestone ledge, Aug. 9, 1911.

Pyrus arbutifolia, var. *atropurpurea* (Brit.) Rob. Shores of Mud Lake in a muck swamp, Starke Co., Sept. 17, 1915.

Pyrus coronaria L. Near Russellville, April, 1910, and May, 1911.

Pyrus ioensis (Wood) Bailey. Two miles west of Greencastle on embankment of old Big Four R. R., Aug. 27, 1911. About 8 feet high.

Pyrus malus L. Three miles south of Russellville on open hillside, May 7, 1911.

Pyrus melanocarpa (Mx.) Willd. Six miles east of Knox in a sandy swamp thicket along roadside, Starke Co., Aug. 25, 1915.

Rosa blanda Ait. Near Crawfordsville on dry bank of old Big Four R. R., below overhead bridge, June 4, 1911.

Rosa carolina L. Five miles south of Russellville on dry hillside, July 9, 1911.

Rosa humilis Marsh. West of Goldsmith frequent along right of way of L. E. & W. R. R., Tipton Co., July 14, 1912. Banks of Wabash River in low sandy soil, Parke Co., July 2, 1911.

Rosa rubiginosa L. Three miles south of Russellville on dry open hillside, June 24, 1911. Four miles south of Russellville on edge of swamp in Raccoon Creek, May 18, 1911.

Rosa setigera Mx. One mile east of Russellville on border of low woods, July 10, 1910.

Rosa virginiana Mill. One mile north of Russellville in a fence row, Montgomery Co., July 7, 1910.

Rubus alleghaniensis Porter. Collected around Russellville on open hillsides, May and June, 1911.

Rubus flagellaris Willd. Around Russellville in fields, May, 1911. Near Tipton on dry silt knoll along L. E. & W. R. R., Tipton Co., June 9, 1912.

Rubus occidentalis L. Four miles east of Russellville on rich wooded hillside, May 22, 1910. One mile north in rich deep woods, Montgomery Co., May 20, 1911.

Rubus pergratus Blanch. Four miles south of Russellville on poor open hillside, flowers, May 22, and fruit, June 11, 1911.

Spiraea salicifolia L. West of Goldsmith along L. E. & W. R. R. in low rich soil, Tipton Co., July 14, 1912.

Spiraea tomentosa L. Five miles southwest of Knox, in a muck swamp, Starke Co., Aug. 7, 1915. Very common in county.

LEGUMINOSAE.

Amorpha canescens Pursh. Two miles east of Judyville along roadside on prairie, Warren Co., July 23, 1914. At junction of Pine Creeks on a dry sandstone ledge.

Amphicarpa monoica (L.) Ell. East of Russellville in dense woods, Sept. 1, 1910. Four miles south in a swamp, Sept. 3, 1911.

Apios tuberosa Moench. Four miles south of Russellville in a swamp, Sept. 3, 1911.

Baptisia leucantha T. & G. West of Goldsmith along L. E. & W. R. R. on a dry bank, Tipton Co., July 14, 1915. Infrequent.

Cassia chamaecrista L. Ballasted bank along Monon R. R. near Crawfordsville, Montgomery Co., Aug. 9, 1910.

Cassia marylandica L. Five miles south of Russellville in fence row along roadside, July 29, 1910. Near Fern along old Big Four R. R.

Cercis canadensis L. Four miles south of Russellville along Raccoon Creek, April 30, 1911.

Desmanthus illinoensis (Mx.) MacM. Near Fern, on right of way of old Big Four R. R., Aug. 8, 1911. Just west of Crawfordsville along railway bank, Montgomery Co., June 4, 1911.

Desmodium bracteosum (Mx.) DC. Three miles south of Russellville in rich woods, Aug. 28, 1910.

Desmodium canadense (L.) DC. Washington Township in sandy alluvial soil along Mill Creek, Aug. 10, 1911. Near Goldsmith on dry knoll along L. E. & W. R. R., Tipton Co., July 14, 1915.

Desmodium grandiflorum (Walt.) DC. Four miles east of Russellville in low rich woods, July 24, 1910.

Desmodium nudiflorum (L.) DC. Five miles south of Russellville on dry rocky hillside with Tsuga, July 29, 1910.

Desmodium paniculata, var. *pubens* T. & G. Four miles south of Russellville in deep woods, Aug. 28, 1911.

Desmodium pauciflorum (Nutt.) DC. North of Russellville in rich woods, Sept. 4, 1910. Three miles south in deep moist ravine, July 30, 1911.

Desmodium rotundifolium (Mx.) DC. Three miles south of Russellville on a wooded hillside, June 12, 1911.

Desmodium sessilifolium (Torr.) T. & G. Three miles east of Knox on sand hills along L. E. & W. R. R., Starke Co., Aug. 20, 1915.

Gleditsia triacanthos L. Three miles south of Russellville in open woods pasture, May 24, 1911. Sandy flood plain of Raccoon Creek, Sept. 3, 1911.

Gymnocladus dioica (L.) Koch. Three miles south of Russellville in a deep open ravine, May 24, 1911.

Lathyrus palustris L. Rocky damp hillside along Sugar Creek, Parke, Co., July 4, 1910.

Lespedeza capitata Mx. West of Goldsmith in dry silt along L. E. & W. R. R., Tipton Co., Aug. 18, 1915. Scarce.

Lespedeza frutescens (L.) Brit. Sugar Creek near Crawfordsville on dry hillside, Montgomery Co., Aug. 9, 1910. Washington Township on dry wooded bank of Mill Creek, Aug. 9, 1911. Two miles northeast of Bainbridge on high dry wooded hill, Aug. 15, 1911.

Lespedeza procumbens Mx. Washington Township near mouth of Mill Creek on dry wooded hillside, Aug. 9, 1911.

Lespedeza violacea (L.) Pers. One and a half miles west of Goldsmith on dry silt, Tipton Co., Aug. 18, 1915.

Lupinus perennis L. Five miles east of Knox on sandy hill along roadside, Starke Co., July 29, 1915.

Medicago sativa L. Dry hillside along Sugar Creek near Crawfordsville, Montgomery Co., Aug. 9, 1910. Near Fern, Aug. 8, 1911.

Melilotus alba Desr. Along roadside near Russellville, July 17, 1910.

Melilotus officinalis (L.) Lam. Roadside near Russellville, May, 1910.

Petalostemon purpureum (Vent.) Rydb. Near Goldsmith on dry Miami silt knoll, Tipton Co., July 14, 1914.

Psoralia onobrychis Nutt. Near Crawfordsville along roadside and on dry hill at Crinoid beds, Aug. 9, 1910. Open damp ravine at Turkey Run, Parke Co., July 2, 1911. Five miles south of Russellville on a clay hillside, Oct. 30, 1910.

Robinia pseudo-acacia L. One mile east of Russellville, July 30, 1911.

Strophostyles helvola (L.) Brit. West of Greencastle on ballasted bank of Monon R. R., Aug. 27, 1911. Three miles south of Russellville in sandy bottom field, Sept. 3, 1911.

Strophostyles pauciflora (Benth.) Wats. Five miles west of Greencastle along old Big Four R. R. right of way, Oct. 4, 1911. Near Fern, Aug. 1911.

Tephrosia virginiana (L.) Pers. Five miles east of Knox on a sand hill, Starke Co., July 20, 1915.

Trifolium agrarium L. Three miles south of Kempton in wheat, July 16, 1912.

Trifolium arvense L. One mile south of Hamlet along roadside, July, 1915.

Trifolium hybridum L. Four miles east of Russellville along roadside, Sept. 24, 1911.

Trifolium pratense L. Along roadside one mile east of Russellville, July 30, 1911.

Trifolium procumbens L. In streets of Crawfordsville, Montgomery Co., June 15, 1910. Near Greencastle along old Big Four R. R., Aug. 27, 1911. In Tipton along L. E. & W. R. R., Tipton Co., July 9, 1915.

Vicia sativa L. Weed in Russellville, July 8, 1914.

Vicia villosa Roth. Weed in Russellville, July 8, 1914.

LINACEAE.

Linum virginianum L. Two miles northeast of Bainbridge on high dry wooded hillside, June 25, 1911.

OXALIDACEAE.

Oxalis corniculata L. Near Russellville in waste ground, Oct. 18, 1911.

Oxalis stricta L. Four miles east of Russellville, rich wooded hillside, May 22, 1910.

Oxalis violacea L. Three miles south of Russellville on rocky hillside, May 21, 1911.

Geranium carolinianum L. Three miles west of Greencastle along right of way of old Big Four R. R., June 4, 1911.

Geranium maculatum L. Five miles south of Russellville in rich shaded soil, May 14, 1910.

RUTACEAE.

Ptelia trifoliata L. East of Russellville in low pasture, June, 1910.

Zanthoxylum americanum Mill. Collected around Russellville in July, 1910, and Sept., 1911.

SIMARUBACEAE.

Ailanthus glandulosa Desf. Near Waveland along Indiana Central R. R. crossing, Sept. 12, 1910. Near Greencastle along traction lines, Aug., 1911. At Hebron, 1911.

POLYGALACEAE.

Polygala sanguinea L. Sterile hillside north of Fern, Aug. 8, 1911. Two miles south of Hamlet in swampy sandy flat, Starke Co., July 26, 1915. Indicator of soil acidity.

Polygala senega L. In damp soil at foot of slopes near Raccoon Creek south of Russellville, July 24, 1911, and July, 1910.

Polygala verticillata L. Dry open clay hillside north of Fern, Aug. 8, 1911. West of Goldsmith in ditch along L. E. & W. R. R., Tipton Co., July 14, 1912. About Mud Lake on wooded sandy ridge, Starke Co., Sept. 17, 1915.

EUPHORBIACEAE.

Acalypha virginica L. One mile east of Russellville along C. H. & D. R. R., Sept. 3, 1911.

Croton glandulosa L., var. *septentrionalis* Muell. Arg. Aug. 27, 1911. Three miles west of Greencastle on bank of old Big Four R. R.

Croton monanthogynus Mx. Near Fern along old Big Four R. R. right of way, Aug. 8, 1911.

Euphorbia commutata Engelm. Moist shaly hillside along Sugar Creek at "The Shades", July 23, 1911. Near Lafayette, dry open hillside, Tippecanoe Co., May 15, 1915.

Euphorbia cyparissias L. Greencastle in waste ground, Aug. 27, 1911.

Euphorbia heterophylla L. Near Fern on right of way of old Big Four R. R., Aug. 8, 1911.

Euphorbia maculata L. Two miles northeast of Bainbridge along Walnut Creek, Aug. 15, 1911.

Euphorbia preslii Guss. One mile east of Russellville along railroad, Aug. 21, 1910.

Euphorbia corollata L. Ballasted bank of Monon R. R. near Crawfordsville, Montgomery Co., Aug. 9, 1910. Embankment of Monon R. R. four miles south of Bainbridge, Aug. 14, 1911.

LIMNATHACEAE.

Floerkea proserpinacoides Willd. East of Russellville in low damp shaded soil, April 20, 1910. South of Russellville in deep moist ravine, May 7, 1911.

ANACARDIACEAE.

Rhus canadensis Marsh. Near junction of Pine Creek on a dry sandstone ledge, Aug. 12, 1914. Happy Hollow near Lafayette, Tippecanoe Co., Apr. 24, 1915.

Rhus copallina L. Four miles south of Russellville on open clay hill, Oct. 5, 1910. Two miles north of Bainbridge on high, dry bluff with *Gaylussacia baccata*.

Rhus glabra L. South of Russellville in a pasture, July 10, 1910.

Rhus toxicodendron L. Four miles east of Russellville on dry hillside, creeping form, July 19, 1910. Four miles west of Greencastle on embankment of old Big Four R. R., June 4, 1911.

Rhus typhina L. Rocky hillside at "The Shades", Montgomery Co., Sept., 1910.

Rhus vernix L. Three miles north of Noblesville, Hamilton Co., Sept. 8, 1912. Common in peat bog.

CELASTRACEAE.

Celastrus scandens L. Four miles south of Russellville on wooded hillside, July 12, 1910. Two miles east on sandstone ledge.

Evonymus atropurpureus Jacq. Five miles south of Russellville in open woods, June 7, 1910.

Evonymus obovatus Nutt. East of Russellville in open woods, Apr. 20, 1910.

STAPHYLEACEAE.

Staphlea trifoliata L. Five miles south of Russellville on rich shady slope near Raccoon Creek, Apr. and May, 1910.

ACERACEAE.

Acer negundo L. Three miles south of Russellville along Raccoon Creek, Sept., 1910. Frequent.

Acer rubrum L. Four miles east of Russellville on high hill, Apr. 16, 1911.

Acer saccharum Marsh. Four miles east of Russellville on dry hillside, Sept. 14, 1911.

Acer saccharum L. Three miles south of Russellville on dry hillside, May 7, 1911.

Acer saccharum, var. *nigrum* (Mx. f.) Britton. Flood plain thicket of Raccoon Creek south of Russellville, June 30, 1911.

SAPINDACEAE.

Aesculus glabra Willd. Three miles northeast of Russellville in open woods, Montgomery Co., Apr. 24, 1910. Flood plain thicket of Raccoon Creek south of Russellville, July 10, 1911.

BALSAMINACEAE.

Impatiens biflora Walt. One mile east of Russellville, Sept. 1, 1910.

RHAMNACEAE.

Ceanothus americanus L. West of Goldsmith along L. E. & W. R. R. on Miami silt, Tipton Co., July 14, 1912.

VITACEAE.

Psedera quinquefolia (L.) Greene. Four miles south of Russellville on wooded hillside, June 18, 1911.

Vitis aestivalis Mx. Three miles south of Russellville on wooded slope June 11, 1911. Poor dry hillside at "Snakes Den" south of Russellville, Oct. 8, 1911.

Vitis cordifolia Mx. Four miles south of Russellville on limestone, June, 1910 and 1911.

Vitis vulpina L. Collected from around Russellville in June and Sept., 1910, and May, 1911.

TILIACEAE.

Tilia americana L. Three miles south of Russellville on rich hillside, July 10, 1910.

MALVACEAE.

Abutilon theophrasti Medic. Weed in Russellville, Oct. 5, 1910.

Hibiscus lasiocarpos Cav. Along Wabash River at mouth of Sugar Creek on border of swamp, Parke Co., Aug. 17, 1911.

Hibiscus militaris Cav. Two miles north of Belle Union beside small pond by roadside, Aug. 13, 1911.

Hibiscus trionum L. Weed in Russellville, Sept. 10, 1911.

Malva rotundifolia L. Crawfordsville in a lawn, Montgomery Co., Aug. 9, 1911. Weed in Russellville, Aug. 17, 1911.

Sida spinosa L. Three miles south of Russellville in sandy soil, Sept. 18, 1910.

HYPERICACEAE.

Hypericum ascyron L. At "The Shades", moist shaly hillside, Montgomery Co., July 23, 1911. Two miles east of Bainbridge, sandy alluvial soil along Walnut Creek, Aug. 15, 1911.

Hypericum cistifolium Lam. On dry bank of Wabash River near mouth of Sugar Creek, Vermillion Co., Aug. 17, 1910. "The Shades", on rocky shore of Sugar Creek, Montgomery Co., July 23, 1911.

Hypericum gentianoides (L.) BSP. Two miles north of Knox, weed in field in acid soil, Starke Co., Aug. 25, 1915.

Hypericum majus (Gray) Britton. South shore of Bass Lake, Starke Co., Aug. 21, 1915.

Hypericum mutilum L. Along Wabash River near mouth of Sugar Creek, in cultivated field, Parke Co., Aug. 17, 1910.

Hypericum perforatum L. Three miles south of Russellville on dry hill, July 31, 1910.

Hypericum punctatum Lam. Four miles east of Russellville on wooded hillside, July 24, 1910.

CISTACEAE.

Lechea racemulosa Lam. South shore of Bass Lake on a sandy knoll, Starke Co., Aug. 21, 1915.

Lechea villosa Ell. Near junction of Pine Creeks on a dry sandstone cliff with *Rhus canadensis*, Warren Co., Aug. 12, 1914.

VIOLACEAE.

Hybanthus concolor (Forster) Spreng. Three miles east of Russellville, dry open hillside, May 1, 1910.

Viola eriocarpa Schwein. Four miles south of Russellville on rich wooded slope, May 5, 1912.

Viola pedata L. Seven miles east of Knox, sandhill along roadside, Starke Co., Aug. 25, 1915.

Viola sororia Willd. Collected south and east of Russellville along Raccoon Creek, Apr., 1910, and May, 1911, 1912. Along Wabash River at Flint, dry rocky soil, Fountain Co., May 19, 1914.

Viola striata Ait. South and east of Russellville along Raccoon Creek, May, 1910, and Apr., 1911.

Viola triloba Schwein. Five miles south of Russellville in rich soil in dense woods, May 29, 1910. Three miles east in wooded ravine, May 12, 1912.

PASSIFLORACEAE.

Passiflora lutea L. Five miles south of Russellville along Raccoon Creek, dry rich soil of wooded slope, Sept. 4, 1910.

THYMELAEACEAE.

Dirca palustris L. Wooded hillside along Raccoon Creek southeast of Russellville, July, 1910, and May, 1911.

LYTHRACEAE.

Lythrum alatum Pursh. North of Tipton in low ground along L. E. & W. RR., June 9, 1912, and one mile west of Goldsmith in low wet ground Tipton Co., Aug. 18, 1912.

MELASTOMACEAE.

Rhexia virginica L. Five and a half miles southwest of Knox, abundant on Clyde fine sand, Starke Co., Aug. 7, 1915.

ONAGRACEAE.

Circaea alpina L. "The Shades" on a decaying log in deep ravine, Montgomery Co., July 23, 1911.

Circaea lutetiana L. "The Shades" in rich deep ravine, Montgomery Co., July 4, 1910.

Epilobium angustifolium L. Two miles south of Hamlet in burned over thicket, Starke Co., July 26, 1915.

Epilobium coloratum Muhl. Four miles south of Russellville in low moist ground, Aug. 21, 1910.

Gaura biennis L. Bank of Wabash River near mouth of Sugar Creek, Parke Co., Aug. 17, 1910. Near Raccoon Creek along C. H. & D. RR., Sept. 10, 1911.

Ludvigia alternifolia L. Three miles south of Hamlet in undrained Clyde fine sandy loam, Starke Co., July 26, 1915.

Ludvigia palustris (L.) Ell. One mile east of Russellville along a stream, Sept. 1, 1910.

Oenothera biennis L. One mile north of Russellville on border of a field, Montgomery Co., July 17, 1910. One mile east of Russellville along railway, July 30, 1911. Near Fern on right of way of old Big Four RR., Oct. 4, 1911.

Oenothera muricata L. One mile east of Goldsmith in low ground along L. E. & W. RR., Tipton Co., July 14, 1912.

ARALIACEAE.

Aralia hispida Vent. Two miles south of Hamlet in burned over thicket. Starke Co., July 26, 1915.

Aralia nudicaulis L. Five miles south of Russellville on dry rocky hillside with Tsuga, Sept. 4, 1910. South of Russellville on sandstone ledge along Raccoon Creek, May 28, 1911.

Aralia racemosa L. Five miles south of Russellville, rich soil in deep woods, July 29, 1910.

Panax quinquefolium L. Three miles south of Russellville in deep woods, May 8, 1910.

UMBELLIFERAE.

Acthusa cynapium L. Three miles south of Russellville in rich moist soil in ravine, May 8, 1910.

Angelica atropurpurea L. South of Russellville, July 3, 1911.

Chaerophyllum procumbens (L.) Crantz. East and south of Russellville in low ground near Raccoon Creek, May, 1910, 1911 and 1912.

Cicuta maculata L. One mile north of Russellville in low ground, Montgomery Co., July 17, 1910.

Conioselinum chinensis (L.) BSP. "The Shades" on a rocky hillside along Sugar Creek, Montgomery Co., Sept. 25, 1910.

Cryptotaenia canadensis (L.) DC. "The Shades" in rich deep ravine, Montgomery Co., July 4, 1910.

Daucus carota L. Near Russellville along roadside, July 30, 1911.

Erigenia bulbosa (Mx.) Nutt. East of Russellville in rich soil of woods, Apr. 24, 1910. Near mouth of Ramp Creek, in deep ravine, Apr., 1911.

Eryngium yuccifolium Mx. West of Goldsmith on Miami silt knoll along L. E. & W. RR., Tipton Co., July 14, 1912.

Osmorhiza claytoni (Mx.) Clark. At "The Shades" in rich deep ravine, Montgomery Co., July 4, 1910.

Oxypolis rigidior (L.) Coult. & Rose. Four miles south of Russellville in a swamp, Aug. 21, 1910. Along Raccoon Creek, on wooded hillside, July 30, 1910.

Sanicula canadensis L. East and south of Russellville on rich woodland, Sept., 1910, and July, 1911.

Taenidia integerrima (L.) Drude. Near Crawfordsville on dry hillside near Crinoid beds, Montgomery Co., July 15, 1910.

Thaspium aureum Nutt. West of Goldsmith on Miami silt along L. E. & W. RR., Tipton Co., July 14, 1912. Bainbridge, July 20, 1911.

Thaspium barbinode (Mx.) Nutt. Five miles south of Russellville on wooded hill, July 9, 1911.

CORNACEAE.

Cornus alternifolia L.f. Wooded hillside along Raccoon Creek south of Russellville, May 11, 1910.

Cornus florida L. Four miles south of Russellville on dense wooded slope, May 1, 1910.

Cornus paniculata L'Her. South of Russellville along Raccoon Creek, June, 1910 and 1911. Three miles north of Tipton on border of oak woods, Tipton Co., June 9, 1912.

Nyssa sylvatica Marsh. Four miles east of Russellville in open woods, May, 1910. Near Fern on dry wooded hill, Oct. 4, 1911. One mile north of Ferndale. Three miles north of West Union on wooded hillside, Aug. 18, 1910.

ERICACEAE.

Andromeda glaucophylla Link. About Mud Lake, floating bog, Starke Co., Sept. 17, 1915.

Chamaedaphne calyculata (L.) Moench. About Mud Lake in muck, Starke Co., Sept. 17, 1915.

Chimaphila maculata (L.) Pursh. One mile north of Ferndale in rich dry woods, Parke Co., Sept. 11, 1910.

Gaylussacia baccata (Wang.) C. Koch. Two miles northeast of Bainbridge along Walnut Creek, on high bluff at "Snowdon Springs", June 25, 1911.

Monotropa uniflora L. Four miles south of Russellville on rich hillside along Raccoon Creek, Oct. 9, 1910. Happy Hollow northwest of Lafayette, on oak slope, Tippecanoe Co., May 18, 1914.

Vaccinium corymbosum L., var. *amoenum* (Ait.) Gray. "The Shades" on very dry bluff at "Devils Backbone", Montgomery Co., Sept. 25, 1910.

Vaccinium vacillans Kalm. Washington Township along Mill Creek on dry rocky hillside, Aug. 9, 1911. Two miles south of Hamlet, Starke Co., July 26, 1915.

PRIMULACEAE.

Dodecatheon meadia L. Four miles east of Russellville on wooded hillside, May 1, 1910.

Lysimachia nummularia L. Near Russellville along a stream.

Samolus floribundus H.B.K. South and east of Russellville along streams, July, 1910, June, 1911.

Steironema ciliatum (L.) Raf. "The Shades" on rocky hillside along Indian Creek in alluvial soil, Montgomery Co., July 4, 1910. One mile north of Russellville in damp low woods, July 17, 1910.

Steironema lanceolatum (Walt.) Gray. Two miles northeast of Bainbridge on dry open hillside, June 25, 1911.

Steironema quadriflorum (Sims.) Hitchc. West of Goldsmith on right of way of L. E. & W. RR., Tipton Co., Aug. 18, 1912.

OLEACEAE.

Fraxinus americana L. Around Russellville in open woods, April and May, 1910 and 1911.

Fraxinus nigra Marsh. South of Russellville in swamps near Raccoon Creek, May and June, 1911.

Fraxinus pennsylvanica, var. *lanceolata* (Borkh.) Sarg. South and east of Russellville in flood plains, May and June, 1911.

Fraxinus quadrangulata Mx. Around Russellville, April, 1910 and 1911.

Ligustrum vulgare L. Near Crawfordsville in hedge on clay hillside, Montgomery Co., July 15, 1910.

GENTIANACEAE.

Gentiana andrewsii Griseb. Three miles south of Russellville near Raccoon Creek, Sept. 18, 1910. "The Shades" in damp ravine, Montgomery Co., Sept. 25, 1910.

Gentiana quinquefolia L. South of Russellville on sandy clay hillside along Raccoon Creek, Oct. 8, 1911.

Gentiana saponaria L. Washington Township near mouth of Ramp Creek, in sandy bottom field, Aug. 9, 1911.

APOCYNACEAE.

Apocynum androsaemifolium L. West of Greencastle on dry bank of old Big Four RR., June 4, 1911.

Apocynum cannabinum L. One mile north of Ferndale along roadside, Parke Co., Sept. 11, 1910. Three miles south of Marshall on dry rocky shore of Sugar Creek, Parke Co., July 2, 1911. Open pasture near Russellville.

ASCLEPIADACEAE.

Acerates hirtella Dennall. West of Goldsmith along L. E. & W. RR. in low moist ground, Tipton Co., July 14, 1912.

Asclepias incarnata L. Three miles south of Russellville along a stream bank, July 31, 1910.

Asclepias phytolaccoides Pursh. Four miles south of Russellville along wooded hillside, June 11, 1911.

Asclepias sullivantii Engelm. One mile west of Bainbridge in open pasture with *A. syriaca*, June 25, 1911.

Asclepias syriaca L. Near Russellville in fields, July, 1910, Aug., 1911.

Asclepias verticillata L. Six miles northwest of Noblesville along Lafayette road on dry gravelly hillside, Sept. 8, 1912, Hamilton Co. Northeast of Tab in pasture on open prairie, Warren Co., July 28, 1914.

Gonolobus laevis Mx. Four miles south of Russellville in a barn lot, July, 1915.

CONVOLVULACEAE.

Convolvulus arvensis L. In waste ground in Tipton, Tipton Co., June 23, 1912. In lawn in Russellville, July 8, 1914.

Convolvulus japonicus Thunb. Three miles north of Tipton along L. E. & W. RR., scarce, Tipton Co., June 9, 1912.

Convolvulus sepium L. Three miles south of Russellville in a swamp, July 30, 1911.

Cuscuta gronovii Willd. South of Russellville along Raccoon Creek on Impatiens, Sept. 4, 1910. South of Russellville in a swamp, Sept. 3, 1911.

Ipomoea pandurata (L.) G. F. Mey. Near Fern on old Big Four RR., Aug. 8, 1911.

Ipomoea purpurea (L.) Roth. Weed in Russellville, Sept. 3, 1911.

POLEMONIACEAE.

Gilia rubra (L.) Heller. Eight miles east of Knox on a sandhill, Starke Co., Aug. 25, 1915.

Phlox bifida Beck. Along Wabash River at Flint in dry rocky soil, Fountain Co., May 19, 1914. Happy Hollow northwest of Lafayette on a dry sandhill, Tippecanoe Co., Apr. 17, 1915.

Phlox divaricata L. Two miles east of Russellville in rich moist woods, Apr. 24, 1910.

Phlox glaberrima L. Five miles southwest of Knox, on swampy fine Clyde sand, Starke Co., Aug. 7, 1915.

Phlox paniculata L. Dry alluvial soil along Raccoon Creek south of Russellville, July 10, 1910. Two miles northeast of Bainbridge, dry alluvial soil along Walnut Creek, June 25, 1911.

Phlox pilosa L. Near Goldsmith, moist bank of L. E. & W. RR., Tipton Co., July 14, 1912. Happy Hollow northwest of LaFayette on dry hilltop, Tippecanoe Co., May 18, 1914.

Polemonium reptans L. North and east of Russellville in rich woods, Apr., 1910, and May, 1911.

HYDROPHYLLACEAE.

Hydrophyllum appendiculatum Mx. Five miles south of Russellville on moist shaly hillside in woods, May 14, 1910.

Hydrophyllum canadense L. Two miles south of Carpentersville on Big Walnut Creek, in deep moist ravine, Aug. 16, 1911.

Hydrophyllum virginianum L. Two miles northeast of Russellville in fence row, June 7, 1910.

Phacelia bipinnatifida Mx. Four miles east of Russellville in rich damp ravine, May 1, 1910. Five miles south, Apr. 17, 1910.

Phacelia purshii Buckley. Four miles east of Russellville in woods, May 22, 1910. In Russellville, 1911.

BORAGINACEAE.

Cynoglossum officinale L. Three miles south of Russellville in open hilly pasture, June 12, 1910.

Lappula virginiana (L.) Greene. Near Russellville in woodland pasture, July 24, 1910. Along Wabash RR. at West Lebanon, Warren Co., July, 1914.

Lithospermum angustifolium Mx. South of Roachdale on dry bank along Monon RR. Tippecanoe Co., May 11, 1915.

Lithospermum arvense L. Along Monon RR. near Ladoga, Montgomery Co., May 5, 1911. Near Russellville station, May 18, 1911.

Lithospermum canescens (Mx.) Lehm. Two miles south of LaFayette along Monon RR. embankment, Tippecanoe Co., May 11, 1915.

Mertensia virginica (L.) Link. Raccoon Creek bank south of Russellville, May, 1910, and Apr., 1911.

Myosotis virginica (L.) BSP. Happy Hollow northwest of LaFayette on dry sandy hillside, Tippecanoe Co., May 18, 1915.

Onosmodium occidentale Mackenzie. Three miles south of Sheridan along I. & L. RR., Hamilton Co., Sept. 8, 1912.

VERBENACEAE.

Lippia lanceolata Mx. Four miles east of Russellville in low ground near Raccoon Creek, July 24, 1910.

Verbena angustifolia Mx. One mile east of Russellville in ditch along railroad, July 10, 1910.

Verbena bracteosa Mx. Near Fern along old Big Four right of way, Aug. 8, 1911.

Verbena hastata L. One mile east of Russellville, July 30, 1911. Near Yountsville in alluvial soil along creek, Montgomery Co., Aug. 10, 1910, and "The Shades" on rocky shore of creek, July, 1911.

Verbena stricta Vent. One mile east of Russellville on bank of railroad, July 10, 1910.

Verbena urticaefolia L. Roadside in Russellville, Aug. 26, 1911. One mile east in low ground, Sept. 10, 1910.

LABIATAE.

Agastache nepetoides (L.) Ktze. Along Raccoon Creek southeast of Russellville in sandy alluvial soil, Sept. 18, 1910.

Agastache scrophulariaefolia (Willd.) Ktze. Three miles north of Sheridan in fence row, Hamilton Co., Sept. 8, 1912.

Blephilia ciliata (L.) Raf. Four miles east of Russellville in rich soil in moist woods, June 19, 1910.

Blephilia hirsuta (Pursh.) Benth. Five miles south of Russellville in deep woods, July 29, 1910.

Collinsonia canadensis L. Three miles south of Russellville in deep woods, Aug. 28, 1910.

Hedeoma hispida Pursh. Four miles east of Russellville in barren pasture, June 24, 1914.

Hedeoma pulegioides (L.) Pers. One mile east of Russellville in open woods, Sept., 1910.

Isanthus brachiatus (L.) B.S.P. Three miles southeast of Russellville on dry hillside, Aug. 28, 1910.

Lamium amplexicaule L. Weed in Russellville, June, 1910, and Apr., 1911.

Leonurus cardiaca L. Near Russellville in waste land, July 17, 1910.

Lycopus virginicus L. East of Russellville along a stream, Aug., 1910.

Marrubium vulgare L. Five miles south of Bainbridge on exposed hillside along Walnut Creek, Aug. 14, 1911.

Melissa officinalis L. One mile east of Carpentersville along roadside, Parke Co., Aug. 16, 1911.

Mentha arvensis L., var. *canadensis* (L.) Briq. Near Russellville along a stream, Sept. 1, 1910.

Mentha arvensis, var. *glabrata* (Benth.) Fernald. Along Wabash River at mouth of Sugar Creek, Parke Co., Aug. 17, 1910.

Mentha piperita L. Near Russellville along a stream, Sept. 1, 1910.

Mentha spicata L. Near Greencastle along old Big Four RR., Aug. 27, 1911.

Monarda fistulosa L. One mile north of Russellville in rich woods, July, 1910. Three miles south on moist clay hillside, July, 1911.

Nepeta cataria L. One mile north of Russellville in rich woods, Montgomery Co., July 17, 1910.

Nepeta hederacea (L.) Trevisan. Four miles east of Russellville in low ground, May 22, 1910.

Physostegia parviflora Nutt. Washington Township, along Mill Creek near its mouth in dry hard soil, Aug. 10, 1911.

Physostegia virginiana (L.) Benth. "The Shades" on dry open bluff, Montgomery Co., Sept. 25, 1910. North of Greencastle along Monon RR., Aug. 27, 1911.

Prunella vulgaris L. East of Russellville in dry soil along railway, July 24, 1910.

Pycnanthemum flexuosum (Walt.) B.S.P. Two miles north of Bainbridge along roadside, June 25, 1911.

Pycnanthemum pilosum Nutt. Two miles south of Russellville on clay bank along roadside, Aug. 9, 1911.

Scutellaria canescens Nutt. Three miles south of Russellville in wooded ravine, July 11, 1910. Washington Township near mouth of Mill Creek in waste field. 1911.

Scutellaria lateriflora L. Near Crawfordsville in a damp ravine, Aug. 9, 1910. Along a stream near Russellville, Sept. 1, 1910.

Scutellaria versicolor Nutt. Three miles south of Russellville on shaded hillside near Raccoon Creek, June 19, 1910.

Stachys hyssopifolia Mx. Two miles south of Hamlet in swamp on fine Clyde sandy loam, July 26, 1915, Starke Co.

Stachys palustris L. One mile east of Russellville along railroad, July 18, 1910.

Stachys tenuifolia Willd. "The Shades" along Sugar Creek, Montgomery Co., July 25, 1911. Four miles south of Russellville in fence row, Aug. 28, 1910.

Synandra hispidula (Mx.) Britton. Five miles south of Russellville along Raccoon Creek in dense woods, May 29, 1910.

Teucrium canadense L. Three miles east of Russellville along railroad, July 24, 1910.

Teucrium occidentale Gray. One mile west of Goldsmith in low swamps, Tipton Co., Aug. 18, 1912.

SOLANACEAE.

Datura stramonium L. Six miles south of Russellville in sandy soil, Oct. 2, 1910.

Datura tatula L. Weed in Russellville, Oct. 2, 1910.

Physalis pubescens L. One mile east of Russellville in open ground, Sept. 1, 1910.

Physalis subglabrata Mack. and Bush. Weed in Russellville, Sept., 1910.

Solanum carolinense L. Woods pasture in Russellville, Sept., 1910.

Solanum nigrum L. Three miles south of Russellville on wooded hill, Sept. 18, 1910.

Solanum rostratum Dunal. Half a mile east of Sheridan in corn, Hamilton Co., Sept. 8, 1912. South of Hebron in a lawn, Aug., 1919.

SCROPHULARIACEAE.

Chelone obliqua L. Three miles south of Russellville in low ground on edge of woods, Aug. 28, 1910.

Collinsia verna Nutt. Three miles southeast of Russellville in rich soil, Aug. 28, 1910.

Gerardia tenuifolia Vahl. Three miles south of Russellville in deep moist ravine, Aug. 21, 1910.

Gerardia virginica (L.) B.S.P. Sugar Creek near Crawfordsville on rich wooded hillside, Montgomery Co., Aug. 9, 1910. Washington Township near mouth of Mill Creek, on dry wooded hillside, Aug. 9, 1911.

Ilysanthes dubia (L.) Barnhart. Four miles south of Russellville along Raccoon Creek, July 24, 1911.

Linaria vulgaris Hill. Near Crawfordsville in gravelly bank of Monon RR., Montgomery Co., June 15, 1910. On old Big Four RR. right of way east of Greencastle, Aug. 27, 1911.

Mimulus alatus Ait. Shore of Wabash River near mouth of Sugar Creek, Parke Co., Aug. 17, 1910.

Mimulus ringens L. Four miles east of Russellville, moist soil on edge of woods, July 24, 1910.

Pedicularis canadensis L. South of Russellville on dry hillside, May 8, 1910.

Pedicularis lanceolata Mx. South of Russellville in a swamp, Aug., 1911.

Pentstemon canescens Britton. Three miles west of Greencastle in low ground along new Big Four RR., June 4, 1911.

Pentstemon hirsutus (L.) Willd. "The Shades" on shaly hillside along Sugar Creek, Montgomery Co., July 4, 1910.

Pentstemon laevigatus Ait. One and a half miles east of Tipton in moist soil along L. E. & W. RR., Tipton Co., June 9, 1912.

Scrophularia marilandica L. One mile north of Russellville in fence row, July 14, 1910. South along Raccoon Creek, Sept. 3, 1911.

Seymeria macrophylla Nutt. Three miles south of Russellville on dry hillside, July 31, 1910.

Verbascum blattaria L. Six miles south of Russellville in dry meadow, July 25, 1911.

Verbascum blattaria L., var. *albiflorum* Ktze. Three miles north of Waveland along roadside, July 4, 1910, Montgomery Co.

Verbascum thapsus L. One mile east of Russellville in woodland pasture, Sept. 1, 1910.

Veronica anagallis-aquatica L. Three miles west of Crawfordsville in a pond, Montgomery Co., Aug. 1, 1910. Central part of Clinton Township in small stream, Aug. 7, 1911.

Veronica arvensis L. Four miles east of Russellville along roadside, May 21, 1910.

Veronica officinalis L. One mile north of Ferndale in dry beech woods, Parke Co., Sept. 11, 1910.

Veronica serpyllifolia L. Washington Township near mouth of Walnut Creek, in deep wooded ravine, Aug. 9, 1911.

Veronica tournefortii C. C. Gmel. Weed in Russellville, Sept. 1, 1910.

Veronica virginica L. Near Goldsmith in moist soil along L. E. & W. RR., Tipton Co., July 14, 1912.

OROBANCHACEAE.

Conopholis americana (L. f.) Wallr. Five miles south of Russellville in dense woods on oak roots, June 5, 1910.

Epifagus virginiana (L.) Bart. One mile east of Russellville on Fagus in flat woods, Sept. 1, 1910.

BIGNONIACEAE.

Tecoma radicans (L.) Juss. Near Russellville, July 10, 1910.

ACANTHACEAE.

Dianthera americana L. "The Shades" on bank of Sugar Creek, Montgomery Co., July 4, 1910. Along Raccoon Creek, south of Russellville, July 30, 1911.

Ruellia ciliosa Pursh. Four miles south of Bainbridge on right-of-way of Monon R.R., Aug. 14, 1911.

Ruellia strepens L. Four miles east of Russellville on dry hillside, June 19, 1910.

PHRYMACEAE.

Phryma leptostachya L. Five miles south of Russellville in deep woods, June 24, 1910.

PLANTAGINACEAE.

Plantago artistata Mx. Two miles northeast of Bainbridge on rocky hillside, June 25, 1911.

Plantago elongata Pursh. Three miles southeast of Russellville in old pasture, June 22, 1914.

Plantago lanceolata L. South of Russellville, in clover field, Aug., 1910. Near Raccoon Creek along C. H. & D. RR.

Plantago major L. In cultivated field two miles south of Russellville, July 30, 1910.

Plantago rugelii Dene. Near Greencastle along Vandalia RR., Oct., 1911.

Plantago virginica L. Weed in Russellville, June 1, 1910.

RUBIACEAE.

Diodia teres Walt. Near Fern on old Big Four RR. right of way, Aug. 8, 1911.

Galium aparine L. East of Russellville in low woods, Apr. 20, 1910.

Galium circaezans Mx. In deep woods south of Russellville, July 1910, 1911.

Galium concinnum T. & G. Four miles east of Russellville in rich soil in woods, June 19, 1910.

Galium tinctorum L. One mile east of Russellville along C. H. & D. RR., June 13, 1915.

Galium triflorum Mx. Five miles south of Russellville in damp ravine, July 9, 1910.

Houstonia purpurea L. South of Russellville, June, 1910, Sept., 1911. "The Shades" on bank of Sugar Creek, Montgomery Co., July 4, 1911. Along L. E. & W. RR., west of Goldsmith in ditch, Tipton Co., Aug. 8, 1912.

Mitchella repens L. Five miles south of Russellville on rocky hillside July 29, 1910.

Lonicera glaucescens Rydb. "The Shades" on rocky hillside, Montgomery Co., Sept. 25, 1910. South of Russellville on dry hillside, July 30, 1911. Along state line road one mile north of Pence in low ground of prairie, Warren Co., July 24, 1914.

Sambucus canadensis L. East of Russellville, roadside, June, 1910.

Symphoricarpos orbiculatus Moench. Along Raccoon Creek south of Russellville, in low ground, July 29, 1910.

Triosteum perfoliatum L. Four miles east of Russellville on wooded hillside, May 1, 1910.

Viburnum acerifolium L. Five miles south of Russellville on rocky bank of Raccoon Creek, May 29, 1910.

Viburnum molle Mx. South of Russellville along Raccoon Creek on wooded slope, June 18, 1911.

Viburnum prunifolium L. One mile east of Russellville in thick woods, Apr. 1910, June 1911. Two miles northeast of Bainbridge on wooded hillside along Walnut Creek, June 25, 1911.

Viburnum pubescens Pursh., var. *indianese* Rehdr[2].

Viburnum venosum Britt. var. *Canbyi* Rehder. South of Russellville along Raccoon Creek, on hillside, June 12, 1910.

VALERIANACEAE.

Valeriana pauciflora Mx. Three miles east of Russellville in very damp ravine, May 22, 1910.

DIPSACACEAE.

Dipsacus sylvestris Huds. South of Russellville on dry hillside, Aug. 29, 1910.

CUCURBITACEAE.

Echinocystis lobata (Mx.) T. & G. One mile north of Ferndale in rich woods, Parke Co., Sept. 11, 1910.

Sicyos angulatus L. Waste ground in Crawfordsville, Montgomery Co., Aug. 9, 1910. South of Russellville in damp ravines, Sept. 1910.

CAMPANULACEAE.

Campanula americana L. Five miles south of Russellville in moist soil of rich woods, July 29, 1910.

Specularia perfoliata (L.) A. DC. Dry open hillside three miles south of Russellville, June 3, 1911.

Lobelia cardinalis L. East of Russellville along railway ditch, Sept. 18, 1910.

[2] According to C. C. Deam, this variety has recently been described from Putnam County specimens sent to the Gray Herbarium by Grimes. It has been assigned number 582b.

Lobelia inflata L. Three miles south of Russellville on a dry hillside, July 31, 1910.

Lobelia leptostachys A. DC. West of Goldsmith along L. E. & W. RR., in ditches, Tipton Co., 1912.

Lobelia siphilitica L. Three miles south of Russellville in low ground, Aug. 21, 1910.

COMPOSITAE.

Achillea millefolium L. Near Russellville in dry soil, July 17, 1910.

Actinomeris alternifolia (L.) DC. Three miles south of Russellville in a swamp, Aug. 21, 1910.

Ambrosia artemisiifolia L. Sandy alluvial soil along Raccoon Creek, south of Russellville, Oct. 2, 1910. Three miles west of Greencastle, Aug. 27, 1911.

Antennaria fallax Greene. Three miles south of Russellville on dry open hillside, April 30, 1910. May, 1912.

Antennaria neglecta Greene. South and east of Russellville on dry open hilltops, April 1911, May 1912.

Anthemis cotula L. South of Russellville on roadside, Sept., 1911.

Arctium lappa L. Weed in Russellville, Oct. 2, 1910.

Artemisia abrotanum L. Three miles west of Carmel in waste ground, Sept. 8, 1910.

Artemisia annua L. "The Shades" in dry alluvial soil along Sugar Creek, Montgomery Co., Sept. 24, 1910.

Aster cordifolius L. Russellville in rich woods, Oct. 2, 1910. Near Fern in rich woods, 1911.

Aster drummondii Lindl. Oct. 8, 1911. Wooded slope along Raccoon Creek, Oct. 8, 1911.

Aster ericoides L., var. *villosus* T. & G. North of Russellville in rich woods, Oct. 2, 1910.

Aster linariifolius L. Rothermal Lake on sandhill on southwest side, Starke Co., Sept. 13, 1915.

Aster multiflorus Ait. Near Roachdale along right of way of Monon RR., Oct. 5, 1911.

Aster novae-angliae L. Two miles south of Russellville in low ground, Sept. 18, 1910. Near Roachdale along right of way of Monon RR., Oct. 5, 1911.

Aster paniculatus Lam. In Russellville along a stream, Oct. 28, 1910.

Aster puniceus L. Three miles south of Russellville in a swamp, Sept. 8, 1910.

Aster sagittifolius Wed. One mile north of Ferndale in deep rich woods, Sept. 1, 1910.

Aster salicifolius Ait. East of Russellville along railway on moist bank, Sept. 24, 1911.

Aster shortii Lindl. One mile north of Ferndale in deep woods, Parke Co., Sept. 11, 1910. "The Shades" in sandy soil along Sugar Creek, Montgomery Co., Sept. 25, 1910. Four miles east of Russellville, Sept., 1911. Bank of Raccoon Creek, south of Russellville, Oct. 8, 1911.

Aster tradescanti L. Weed in Russellville, Oct. 2, 1910.

Aster umbellatus Mill. Three miles north of Noblesville in muck and peat, Hamilton Co., Sept. 8, 1912. Six miles east of Knox on edge of woods, Starke Co., Aug. 25, 1915.

Bidens aristosa (Mx.) Britt. Four miles south of Russellville along Raccoon Creek, Sept. 10, 1911.

Bidens bipinnata L. One mile east of Russellville in wet beech woods, Sept., 1910.

Bidens cernua L. South of Russellville in wet beech wood, Sept., 1911.

Bidens laevis (L.) B. S. P. Russellville, Sept. 1, 1910.

Cacalia atriplicifolia L. Four miles east of Russellville in rich soil along stream, July 24, 1910.

Cacalia reniformis Muhl. Three miles south of Russellville in swamp.

Chrysanthemum balsamita L., var. *tanacetoides* Boiss. Near Limedale on embankment of Vandalia RR., Oct. 5, 1911.

Chrysanthemum leucanthemum L. One mile east of Russellville along railroad, July 10, 1910.

Cichorium intybus L. Along roadside four miles south of Russellville, July 14, 1911.

Cirsium altissimum (L.) Spreng. Three miles south of Russellville in a swamp, Aug. 21, 1910.

Cirsium arvense (L.) Scop. At Monon and C. H. & D. railroad crossing at Roachdale on embankment, Aug. 27, 1911.

Cirsium discolor (Muhl.) Spreng. South of Russellville on dry hillside, Aug. 25, 1910. Near Roachdale on right of way of Monon RR., Oct. 5, 1911.

Cirsium lanceolatum (L.) Hill. One mile east of Russellville in a pasture, Sept., 1910.

Cirsium muticum Mx. Three miles north of Noblesville in muck and peat, Hamilton Co., Sept. 8, 1912.

Coreopsis tripteris L. Half a mile west of Goldsmith on right of way of L. E. & W. RR., Tipton Co., Aug. 18, 1912.

Dyssodia papposa (Vent.) Hitch. East of Noblesville along roadside. Hamilton Co., Sept. 8, 1912.

Eclipta alba (L.) Hassk. Two miles east of Carpentersville on Big Walnut Creek, moist rocky bank, Aug. 16, 1911.

Erechtites hieracifolia (L.) Raf. One mile east of Russellville in rich woods, Sept. 1, 1910.

Erigeron annuus (L.) Pers. Near Russellville in timothy field, July, 1910.

Erigeron canadensis L. Near Russellville in field, Sept. 1, 1910.

Erigeron philadelphicus L. Five miles south of Russellville in open hillside, June 12, 1910.

Erigeron ramosus (Walt.) B. S. P. Near Russellville in field, July 17, 1910.

Eupatorium altissimum L. Russellville, Sept., 1910.

Eupatorium coelestinum L. Rocky shore of Mill Creek, Aug. 9, 1911. Washington Township.

Eupatorium perfoliatum L. One mile east of Russellville on low damp ground, Sept., 1910.

Eupatorium serotinum Mx. Near Russellville on rich hillside, Sept., 1910.

Eupatorium urticaefolium Reichard. South of Russellville on rich hillside, Aug. 21, 1910.

Galinsoga parviflora, var. *hispida* DC. In Russellville, Apr. 20, 1911.

Gnaphalium polycephalum Mx. Three miles south of Russellville on dry hillside, Aug. 28, 1910.

Helenium autumnale L. Near Russellville along a stream, Sept. 1, 1910.

Helianthus decapetalus L. Five miles south of Russellville on edge of woods, Sept. 4, 1910.

Helianthus grosseserratus Martens. West of Goldsmith along L. E. & W. RR., on Miami silt, Aug. 18, 1912.

Helianthus microcephalus T. & G. South of Russellville on dry hillsides, Aug., 1910, and Sept., 1911.

Helianthus mollis Lam. On right of way of Monon RR., west of Greencastle, Aug. 27, 1911. West of Kempton on right of way of L. E. & W. RR., Tipton Co., Aug. 18, 1912. Six miles east of Knox on edge of wood, Starke Co., Aug. 25, 1915.

Helianthus strumosus, var. *mollis* T. & G. One mile west of Goldsmith on L. E. & W. RR. tracks, Tipton Co., Aug. 18, 1912.

Helianthus tuberosus L. South of Russellville along Raccoon Creek, Sept. 4, 1910.

Heliopsis helianthoides (L.) Sweet. South of Russellville along Raccoon Creek, Aug. 21, 1910.

Hieracium paniculatum L. Five miles south of Russellville on dry hillside, Sept. 4, 1910.

Hieracium scabrum Mx. One mile north of Ferndale in dry woods, Sept. 11, 1911, Parke Co.

Inula helenium L. Two miles south of Russellville along roadside, July 9, 1910.

Krigia amplexicaulis Nutt. Happy Hollow northwest of LaFayette on dry wooded hillside, June 4, 1914.

Krigia virginica (L.) Willd. Seven miles east of Knox on sandhill along roadside, Starke Co., Aug. 25, 1915.

Kuhnia eupatorioides L. North of Greencastle on bank of Monon RR., Aug. 27, 1911.

Lactuca canadensis L. One mile east of Russellville in moist grounds, July, 1910 and Sept., 1910.

Lactuca scariola L. Near Russellville along roadsides, Aug. 26, 1911.

Lactuca spicata (Lam.) Hitchc. Six miles south of Russellville in rich woods, Oct. 16, 1910.

Lactuca villosa Jacq. Five miles south of Russellville along roadside, rich soil, Sept. 4, 1910.

Lepachys pinnata (Vent.) T. & G. West of Goldsmith on bank of L. E. & W. RR., Tipton Co., July 14, 1912.

Liatris cylindracea Mx. Two miles south of Hamlet, on sandhill along roadside, Starke Co., July 26, 1915.

Liatris scariosa Willd. In sand at edge of Mud Lake, Sept. 17, 1915.

Liatris spicata (L.) Willd. Near Goldsmith in moist soil, Tipton Co., July 14, 1912.

Parthenium integrifolium L. West of Kempton on dry knoll along L. E. & W. RR., Tipton Co., Aug. 18, 1912.

Polymnia canadensis L. On old Wabash-Erie Canal bank, Parke Co., Aug., 1910. Near Fern on rocky hillside along Walnut Creek, Aug. 8, 1911. Five miles south of Russellville, July, 1915.

Prenanthes alba L. "The Shades" on moist shaly hillside, Montgomery Co., Sept. 15, 1910.

Prenanthes altissima L. Four miles south of Russellville on edge of woods, Sept. 4, 1910.

Prenanthes altissima, var. *cinnamomea* Fern. Six miles south of Russellville in rich woods, Oct. 16, 1910.

Prenanthes crepidinea Mx. Five miles south of Russellville in rich low ground, Sept. 4, 1910. One mile north of Russellville in rich woods, Oct. 2, 1910.

Prenanthes racemosa Mx. West of Goldsmith along L. E. & W. RR., in low ground, rare, Tipton Co., Aug. 18, 1912.

Rudbeckia hirta L. Two miles east of Waveland in a field, Montgomery Co., July 4, 1910.

Rudbeckia laciniana L. South of Russellville along Raccoon Creek, Aug. 1910.

Rudbeckia subtomentosa Pursh. One mile west of Goldsmith on silt, Tipton Co., July 14, 1912.

Rudbeckia triloba L. South of Russellville along Raccoon Creek, July, 1910.

Senecio aureus L. Three miles south of Russellville in a swamp, May, 1910.

Senecio obovatus Muhl. Four miles east of Russellville on wooded hillside, May 1, 1910. Three miles south, April, 1911.

Silphium asteriscus L., var. *laevicaule* DC. Two miles west of Crawfordsville along Big Four RR., Montgomery Co., Aug. 10, 1910.

Silphium laciniatum L. West of Goldsmith along L. E. & W. RR., July, 1912.

Silphium perfoliatum L. South of Russellville along Raccoon Creek, Aug., 1910.

Solidago caesia L. Three miles south of Russellville in rich woods, Sept. 18, 1910.

Solidago canadensis L. Five miles south of Russellville, Sept., 1910.

Solidago graminifolia (L.) Salisb. South of Russellville in poor soil on edge of fields, Sept. 17, 1911.

Solidago juncea Ait. "The Shades" on rocky hillside along Indian Creek, Montgomery Co., July 4, 1910. West of Goldsmith along L. E. & W. RR., Tipton Co., July 17, 1915. Three miles north of Noblesville, Sept. 8, 1915.

Solidago latifolia L. Three miles south of Russellville along Raccoon Creek, Sept. 18, 1910.

Solidago patula Muhl. Three miles south of Russellville in a swamp, Sept. 18, 1910.

Solidago rigida L. West of Goldsmith along L. E. & W. RR., Tipton Co., Aug. 3, 1915.

Solidago serotina Ait. Three miles south of Russellville, Sept. 3, 1911. Low damp ground east of Raccoon along C. H. & D. RR., Sept. 10, 1911.

Solidago ulmifolia Muhl. South of Russellville on rich wooded hill, Sept. 4, 1910, and Oct., 1911.

Sonchus oleraceus L. Weed in Crawfordsville, Sept., 1910.

Tanacetum vulgare L. Roadside in Russellville, Sept. 1, 1910.

Taraxicum officinale Weber. Weed in Greencastle, Oct. 5, 1911.

Tragopogon pratensis L. On embankment of L. E. & W. RR., in Kempton, Tipton Co., July 14, 1912.

Vernonia altissima Nutt. One mile east of Russellville in pasture, Sept. 1, 1910.

Vernonia fasciculata Mx. One mile south of Kempton, Tipton Co., July, 1912. Three miles west of Knox in a meadow, Starke Co., Aug., 1915. Ferndale, Sept. 11, 1910.

Vernonia missurica Raf. Half a mile north of Ferndale along a limestone ledge near a stream, Parke Co., Sept. 11, 1910.

INDIANA PLANT DISEASES, 1921.[1]

MAX W. GARDNER[2], Purdue University.

This is the third of a series of annual reports (16, 17)[3], the object of which has been to summarize the plant disease situation in Indiana. This report is based upon our records and observations during the season of 1921 and the plan outlined in the 1919 report (16) has been followed. As in these previous reports, no claim for completeness is made. Of necessity, our attention has been confined largely to agricultural crops and the diseases of economic importance. The diseases are arranged alphabetically by hosts except that under the headings, "Forest and Shade Trees" and "Ornamentals", near the end of this report are grouped such fragmentary records as we have relative to the diseases of such plants. For further information relative to parasitic fungi in Indiana the papers by Jackson (27, 28), Anderson (1), and Van Hook (41), should be consulted. Many of the diseases are well illustrated in the annual reports of the State Entomologist of Indiana, 1907 to 1916. The geographic distribution and economic importance of the various Indiana crops have been reported by Bryant (6).

WEATHER CONDITIONS.

The season of 1921 in Indiana was characterized by most peculiar weather conditions. The winter of 1920-21 was exceptionally mild and open. The graphs in figure 1 illustrate the departures from normal temperature and rainfall during the growing season based upon the monthly averages given by J. H. Armington, of the U. S. Weather Bureau, in the Indiana section of "Climatological Data."

These figures show that March and April were exceptionally warm and wet, while during late May, June and July, the weather was especialy hot and dry, culminating in a destructive drouth in July. The marked feature of the summer, however, was the very high rainfall during August and September with a very high temperature for the latter month. This resulted in truly tropical conditions which, of course, exerted a marked influence on the plant disease situation in Indiana.

The mild, open winter probably favored the severe attack of rye anthracnose in northern Indiana, the fungous foot-rot of rye and wheat, and the wheat leaf rust epiphytotic in southern Indiana. The unusually warm, early, and wet spring probably increased the severity of rye anthracnose, raspberry anthracnose, strawberry leaf-spot, early infection of apple scab, apple blotch, peach bacterial spot, and black-leg on cabbage seedlings. The late frosts of March 29, April 10-11, and April 18 completely ruined tree fruits in central and southern Indiana. Not so much damage was done in the northern part of the state.

[1] Contribution from the Botanical Department, Purdue University Agricultural Experiment Station, Lafayette, Indiana. Presented at the 1922 meeting.

[2] The writer wishes to acknowledge the assistance and co-operation of H. S. Jackson, E. B. Mains, J. B. Kendrick, G. N. Hoffer, C. T. Gregory and R. J. Hosmer, C. L. Burkholder, F. P. Cullinan, F. C. Gaylord, H. D. Brown, I. C. Hoffman and C. E. Baker.

[3] Numbers in parenthesis refer to "literature cited".

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

The dry weather of May and the extreme heat and drouth of June and July greatly aggravated tomato Fusarium wilt and yellows in early cabbage, and caused a heavy loss in stand in late potatoes because of rotting of the seed pieces soon after planting. Beet leaf-spot was much worse than usual. The dry weather probably checked apple scab and wheat scab, but greatly accentuated the leaf rust damage in wheat because of the excessive evaporation from the leaves.

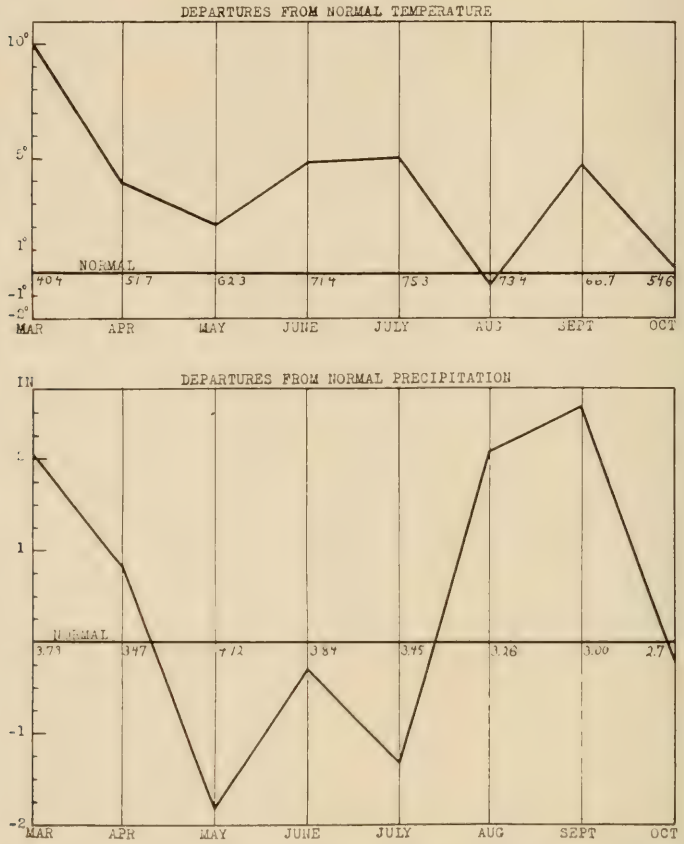

Fig. 1. Indiana weather conditions, 1921. Graphs represent departures from normal temperature and precipitation as shown by the monthly averages for the state as a whole.

The mild, very wet August probably lessened the severity of cabbage yellows, potato wilt, and tomato blossom-end rot in the canning crop. However, the excessive rainfall of August and September and high temperature of the latter month undoubtedly was the cause for the greatly increased severity of watermelon anthracnose in central Indiana, grape black rot, apple black rot, and other fruit rots including that caused by a Phytophthora, potato early blight, various powdery

mildews, corn ear rots, tomato fruit rots following growth cracks, and a local outbreak of buckeye rot of tomato. However, such weather was also particularly favorable to the luxuriant growth of late truck crops and extraordinary yields were obtained this season. The first general killing frost occurred October 13. The long growing season and late fall prolonged the activity and increased the severity of tomato leaf-spot, apple scab, apple frogeye leaf-spot, and the corn ear rots. The corn ear rots were also aggravated by the heavy rains and floods in November.

DISEASES ARRANGED BY HOSTS.

Alfalfa—Leaf-spot caused by *Pseudopeziza medicaginis* was found severe in a field in Marion county and was noted on specimens from Greene county. This disease is co-existent with its host. Gregory noted the leaf-spot caused by *Pyrenopeziza medicaginis* in Warren county. Mains noted the rust (*Uromyces medicaginis*) at Lafayette.

Apple—Since the frost ruined the apple crop in the blotch region (southern Indiana) the blotch sprays were generally omitted and as a consequence of this fact as well as the favorable weather, apple blotch (caused by *Phyllosticta solitaria*) was especially prevalent on the foliage and on what little fruit remained in the case of the susceptible varieties. Gregory noted fruit infection in Floyd County as early as June 4, and Baker found fruit infection on Northwestern at Knightstown on June 10. In an experimental orchard at Laurel, Cullinan noted some blotch infection on Grimes fruit and incriminated a badly cankered Northwestern tree near by as the source of infection. Cullinan also found a few fruit lesions on Stayman in a young orchard near Lafayette on Sept. 28, and the source of infection here was not located. In an orchard near Mooresville there was spread of infection from a row of badly cankered Northwestern to the fruit of the varieties Ben Davis, Stark, York, Grimes, and Jonathan. It was rather severe on the York. A few fruit lesions on Ben Davis were noted at Peru, and a few cankers were noted on Oldenburg and Stark trees in Miami County. In an orchard of young Oldenburg trees at Vincennes, the occurrence of old blotch cankers scattered here and there was indicative of blotch introduction with nursery stock.

In an orchard of mixed varieties near Mitchell, a row of Oldenburg trees was very heavily infected. Observations on the adjacent trees of other varieties revealed a few blotch cankers on the varieties Akin, Ben Davis, Champion, Gideon, Summer Rambo, and Salome. In each case these cankers were on the side of the tree next to the Oldenburg trees. Blotch seemed, however, to be enphytotic in one isolated Summer Rambo tree. Single trees of the varieties Winesap, Delicious, Wealthy and Celestia, as well as two Salome trees similarly exposed to the Oldenburg row, showed no cankers.

The Bordeaux blotch sprays (2, 4, and 6 weeks after petal fall) again gave good control of fruit infection on Northwestern at Knightstown, and practically perfect control of leaf infection in this orchard as well as on the same variety at Mooresville, on Oldenburg at Mitchell, and on Ben Davis at Solon. In all cases, leaf petiole infection on un-

sprayed check trees was very prevalent and in certain cases was found so severe as to kill the leaves outright. Petiole infection is an important feature in the life history of this fungus since it has been found that a very high percentage of the twig cankers are at leaf scars and are the result of mycelial invasion from petiole lesions (19). Thus by controlling petiole infection, canker formation will be largely prevented. Observations at Knightstown show that spraying has practically prevented all canker formation on the wood formed the years the sprays were applied. R. A. Simpson, at Vincennes, likewise has prevented canker formation with frequent Bordeaux sprays. The importance of spraying every year, regardless of crop, is, of course, evident. Observations indicate that as a summer spray lime-sulphur is not as effective against blotch as Bordeaux mixture.

Burkholder reports that the disease occurs here and there in northern Indiana, mainly on the Mann and Oldenburg varieties, both of which are frequently grown in home orchards. The same observer noted blotch this year in DeKalb, Allen, and Noble Counties and it has been reported from Elkhart and Marshall counties.

Scab caused by *Venturia inaequalis* was worse than usual on the foliage this year, not only owing to the early wet spring weather but on account of the great difficulty experienced in properly applying the sprays because of the protracted blooming period which, according to Cullinan, covered almost a month in some localities. In some cases the pink spray or first summer spray was entirely omitted. Undoubtedly the June-July drouth checked scab. H. H. Swaim reported that in spite of its early severity, the disease was well controlled later. Burkholder reports scab worse in northern Indiana than in 1920, especially on Winter Banana in DeKalb County and in Wabash County. Gregory reported scab severe in Floyd, Decatur, and Shelby counties. Complaints accompanied by scab specimens were received in June from Allen, Clay, Ripley, Steuben, Hendricks, and Wabash counties. Severe foliage infection was noted at Mooresville, Paoli, Peru, and Vincennes early in the season.

Some observations upon varietal susceptibility to scab were made in an unsprayed orchard near Mooresville in September. Foliage infection was severe on Maiden Blush, Pewaukee, Chenango, Benoni, Wealthy, Northwestern, Stark, Jonathan and Indiana Favorite, and was present to some extent but not severe on Grimes, Winter Maiden Blush, and York, while none was noted on Transparent. Fruit infection was noted on Maiden Blush, Wealthy, York, and Jonathan. Burkholder reports severe scab on the Delicious variety. At Peru scab was noted much worse on Ben Davis than on Grimes—in fact practically none was noted on Grimes foliage in October. Unsprayed Ben Davis trees showed very abundant foliage infection of scab in May and in October the disease had caused severe defoliation and a total loss of the crop because of the undersized, malformed, scabby fruit. The Ben Davis fruit responded in a peculiar manner to scab infection in that there was marked hypertrophy of the tissue beneath older lesions resulting in conspicuous protuberances on the fruit. In other cases old lesions had checked the

normal growth of the fruit, resulting in cracks and the entrance of rot-producing fungi.

Observation this year on black rot, caused by *Physalospora cydoniae*, gave convincing evidence of the destructiveness of the canker stage of the disease. Complaints accompanied by specimens were received from Fulton and Marshall counties and the serious effects of black rot cankers on Ben Davis trees in an orchard near Peru were very striking inasmuch as many of the larger limbs were being killed. It seemed likely that the fungus might be following winter injury in this case. Black rot was also found causing cankers around 17-year-locust injury on 1918 wood of young Grimes trees near Paoli. The black rot fungus also is a very common secondary invader of blotch cankers.

The frog-eye leaf-spot caused by the black rot fungus was exceedingly prevalent this year throughout the state. The lesions were larger than usual, showing a zone of secondary enlargement around the original circular spot. Frog-eye was noted as early as April 28 at Vincennes. In one orchard in Orange County, much of the yellowing and defoliation during the drouth of June and July was attributable to this disease and the same holds true for unsprayed orchards in general. In an orchard of mixed varieties near Mooresville, observations made on Sept. 15 showed frog-eye to be severe on Ben Davis, Maiden Blush, Pewaukee, Yellow Transparent, Chenango, Wealthy, Winter Maiden Blush, and Northwestern, less prevalent on Benoni, Grimes, Stark, and Jonathan, and absent on Indiana Favorite and York. Near Peru, frog-eye was noted to be much less common on Grimes than on Ben Davis foliage. In this orchard there was not much difference between unsprayed and sprayed trees in the prevalence of frog-eye leaf-spot. Counts were made on the leaves of Ben Davis trees sprayed with Bordeaux for blotch control in Clark county and it was found that 60 per cent of the unsprayed leaves showed frog-eye leaf-spot as compared with 45 per cent of the sprayed leaves. This shows that a 2-4-6 weeks spray schedule does not control this disease.

Fruit infection with black rot was much worse than usual this year, owing probably to the wet August and September. Calyx-end rot of young fruit was observed in Henry County, on July 20 and on Sept. 15 the same type of rot was noted on York in Morgan county. Black rot was also noted on Grimes and Jonathan in the latter orchard. Cullinan reported serious losses due to black rot of Grimes and other varieties in orchards in Franklin, Henry, and Miami counties due to the wet weather. The prevalence of growth cracks, especially in Stayman, also increased the losses throughout the state from black rot, according to the same observer. Windfalls were in general a total loss.

Fire blight, due to *Bacillus amylovorus*, was in general less severe than usual this year. Gregory observed destructive blight in Floyd, Decatur, and Shelby counties and Cullinan reported fire blight severe on Jonathan in an orchard in Franklin county, while Grimes, King David, Stayman, Delicious, and Winesap in the same orchard were not affected. Burkholder noted fire-blight in Adams County and in Elkhart County the disease was found prevalent in a small orchard containing

two pear trees as sources of infection. G. W. Cochran was unable to locate any active fire blight in the neighborhood of LaFayette.

Blister canker caused by *Nummularia discreta* is of very considerable importance in central and southern Indiana, especially in the older orchards of the Ben Davis variety. Its occurrence near Greencastle has been previously reported. Specimens were received from Posey county and the disease is reported on Ben Davis in orchards in Brown and Jay counties. Blister canker was found destructive on a few older trees in an orchard in Orange County and in an orchard in Miami County it is causing serious injury to both Grimes and Ben Davis. In the latter instance the disease has apparently followed winter injury and is actively killing the limbs which were conspicuous this season because of the yellow foliage and dwarfed fruit. On October 5, new stromata were found under the lenticels in recently infected bark, and many fresh stromata had burst through the lenticels producing star-shaped ruptures. The nail-head stromata on the older parts of the cankers are, of course, conspicuous and characteristic. Growers report poor success with attempts to eradicate the disease by cutting-out methods. However, in certain orchards observed, blister canker has affected only a few trees and determined efforts to eradicate such centers of infection should be made. In case removal of all diseased wood is impracticable it is advisable to shave off the bark to prevent spore production, as Anderson (Ill. Cir. 258) has recently recommended.

Rust (*Gymnosporangium juniperi-virginianae*) was noted on the foliage of York and Jonathan in Orange County, on Jonathan in Morgan County, and on Wealthy foliage in Lawrence and Henry counties. Serious difficulty with rust is reported from Brown county. The wide prevalence of red cedar in southern Indiana insures an annual rust infection of the susceptible apple varieties and as a rule no eradication of the cedars has been attempted.

Powdery mildew (*Podosphaera oxycanthae*) was found very severe on the young leaves of young Winesap trees at Vincennes, April 28, on young sprayed Transparent and Carson trees in Morgan county on May 12 by C. E. Baker, and in the fall on young trees in Lawrence county. The wet weather of early spring and later summer probably favored this disease. Burkholder reports that crown gall and hairy root, due to *Bacterium tumefaciens*, is often present on apple nursery stock received by Indiana growers.

This was an epidemic season for sooty blotch and fly-speck, caused by *Glocodes pomigena* (7) and *Leptothyrium pomi*. Burkholder reports this trouble from Gibson and Pike counties and observed that an extra spray applied about August 1, gave a good control. Cullinan did not find the disease severe in sprayed orchards. In an unsprayed orchard in Morgan County, this disease was noted Sept. 15 on Ben Davis, Maiden Blush, Pewaukee, Grimes, Wealthy, Northwestern, Jonathan, Indiana Favorite, and York. It is especially objectionable, of course, on such light-skinned varieties as Grimes, Maiden Blush, and Northwestern, and on York it was noted that the red coloration was absent underneath the sooty blotches.

The occurrence of a rather destructive rot of apples caused ap-

parently by *Phytophthora cactorum* in three localities in the state is of considerable interest since this disease, which is common in Europe, has been previously reported in this country only from New York (42) and a few other localities. The disease was first noted early in September on Grimes fruit from three trees in a low area in an orchard at LaFayette. It was found mostly on fallen apples and occasionally on low-hanging fruit on the trees. Since it was rather inconspicuous in its early stages, it was overlooked in sorting and later showed up at an alarming rate in the baskets of sorted fruit. It caused a loss of about 10 per cent of the crop from the three trees mentioned. The external appearance of the rot (fig. 2) was a rather indefinite, light brown discoloration of irregular intensity and the infected flesh was firm and at first only slightly discolored with the veins distinctly browned. The rot rapidly involved the entire fruit. Infection no doubt originated from the soil and the heavy rains and presence of standing water under these trees undoubtedly facilitated the development of the

Fig. 2. Phytophthora rot of Grimes apples. At the right, field appearance of the disease; at the left, outgrowth of fungus in a damp chamber.

fungus. Cullinan found this disease on Grimes and Ben Davis fruits on the ground in an orchard in Miami County, Sept. 16, and on Oct. 5 a few remaining specimens were found. The disease had caused a marked loss in the Grimes variety and occurred only in the low places in the orchard. In an orchard in Henry County, Phytophthora rot was found on Northwestern apples, Sept. 27. The extremely heavy rains of August and September are considered responsible for the outbreak of this disease and its apparent spontaneous appearance in three orchards would indicate that the fungus may be a common soil inhabitant.

Bitter rot due to *Glomerella cingulata* was present to a limited extent on Grimes fruit in an orchard in Franklin County according to Cullinan. The same observer also found a case of brown rot, caused by *Sclerotinia cinerea*, on a Jonathan apple at Lafayette. A peculiar fruit spot, somewhat resembling Brook's fruit spot, but apparently non-parasitic in nature was noted by Burkholder on King David apples grown in Hendricks County and specimens were also received from Henderson, Ky.

Burkholder reported that Jonathan spot (cause unknown) was worse this year than he had noted previously and attributed this to the early ripening of the Jonathan variety. Cullinan also reported this trouble worse than usual, and many growers have expressed great concern about this disease, stating that it is of great importance and necessitates immediate consumption of the fruit. An opinion was expressed that Jonathan spot is worse on lower sites in southern Indiana. The disease also occurs on the King David variety and was noted on the Hubbardston variety at Goshen. Cullinan reported that bitter pit (cause unknown) was common on Grimes, Baldwin, and Arkansas in Franklin County. Burkholder was inclined to associate the severity of bitter pit on Baldwin this year with the early ripening. Water core (cause unknown) was noted on a few Northwesterns in an orchard in Henry County.

A peculiar type of canker following 17-year-locust injury of 1918 on Grimes limbs was sent in from an orchard in Brown County. Healing had been prevented and the callus had been killed back annually. Both old and new calluses were abundantly covered with sporulating acervuli of a species of Hyaloceras. In this same orchard was found another distinctive type of canker[1] on old and young twigs of the Champion variety. On young twigs these cankers were black in color and circular with an even, definite margin, and on older limbs were more or less circular and elevated, often with a peripheral crack not unlike fire blight cankers. Preliminary efforts to isolate an organism have been unsuccessful.

The destructiveness of the collar rot of the Grimes variety has been previously reported. In one row of Grimes in an orchard in Morgan County, ten trees have been killed by this trouble. Collar rot was noted on Grimes in Miami County and was reported in six-year-old trees in Fulton County but in general is not as destructive in northern as in southern Indiana. Collar rot was noted on young Oldenburg trees at Vincennes and Cullinan reported that it also occurred on the varieties Rhode Island and Tompkins King. In new orchards this difficulty with Grimes is being met by using double-worked trees and in old orchards inarch grafts have been used to save the affected trees.

Another trouble apparently distinct from collar rot is the root-rot which occurs, according to Burkholder, in practically all varieties planted on recently cleared land in the "sassafras" region embracing Brown, Monroe, Greene, Daviess, Martin, Lawrence, Orange, Washington and Jackson counties or parts thereof. In an experimental orchard near Bedford eleven trees including Northwestern, Grimes, Arkansas, Indian, and Ben Davis died in the fall of 1920 as a result of root rot and in 1921 six more died, including Grimes, Rome, Northwestern, Jonathan, and Ben Davis. A grower in Orange County reported root rot present on Stayman, Jonathan, and Rome and worst on Delicious, and a grower in Brown County reported much difficulty with root rot. Near Mitchell, Oldenburg and Gideon trees were observed which were

[1] Later found to be identical with the non-parasitic brown bark spot of Montana. (Swingle, D. B., and Morris, H. E. The brown bark spot of fruit trees. Mont. Agr. Ex. Sta. Bul., 146:1-22, 1921.)

dying apparently from root-rot. A grower brought in a specimen of a 12-year-old tree from an orchard in Martin County that had died from root rot and reported that it was very destructive in the neighborhood of Indian Springs and Trinity Springs. The varieties affected were Stayman, Grimes, and Willow. Careful inspection of a large orchard planted on old farming soil in this root-rot region revealed no cases of root rot whatever and leads to the inference that the disease is associated usually with newly cleared soil.

Winter injury, evidenced by the death of the bark on one side of the trunk and limbs, in the crotches, and often about the crown, is a serious trouble on young trees throughout the state. It also occurs on old trees and no doubt is often associated with the two troubles described above. Much of the winter injury, according to Oskamp (32), is due to the 1917-18 season.

Frost injury to Ben Davis fruit in an orchard in Miami County produced conspicuous russet or buckskin blotches with lace-like margins on about 50 per cent of the fruits and in many instances there was extreme hypertrophy of the fruit tissue under this russetted area causing a peculiar malformation of one side of the fruit. Characteristic foliage injury was caused by the late frosts. Portions of the lower epidermis and areas of the leaf blade were often killed outright and the subsequent result was a crinkling, rolling and stunting of the older leaves many of which turned yellow and dropped prematurely.

There was considerable spray injury this season. Cullinan noted Bordeaux spray injury to Grimes, Wagener, and Maiden Blush foliage at LaFayette, which resulted in marked defoliation in June soon after the spray was applied. Marginal injury of the leaves as a result of summer spraying with lime-sulphur was noted in Henry County in July and arsenate injury to foliage, consisting of circular reddish brown spots, was noted in Miami County. The Bordeaux blotch sprays caused a marked injury to Ben Davis foliage in Clark County.

Barley.—Loose smut (*Utilago nuda*) was very common. Gregory reported good control with hot water seed treatment in Blackford, Hancock, Henry and Jasper counties and also reported that in Carroll County the Oderbrucken No. 8, an improved variety from Wisconsin, showed resistance to loose smut. Jackson reported the occurrence of covered smut (*Ustilago hordei*) on winter barley near Lafayette while none was noted on spring barley. The same observer also noted stripe, caused by *Helminthosporium gramineum*, and spot blotch, caused by *H. sativum*. Gregory noted the stripe severe in one field in Hancock County. Mains noted a very little stem rust (*Puccinia graminis*) near Lafayette and reported the presence of a very small amount of leaf rust (*Puccinia simplex*) in the state.

Bean.—As usual, bacterial blight, caused by *Pseudomonas phaseoli*, was the most serious disease of beans in the state, and was very prevalent in the Indianapolis market gardens. It was also noted at Plymouth and Goshen and in a field in Tippecanoe County. Mains grew about 60 varieties of beans in parallel rows in an experimental garden at Lafayette and bacterial blight occurred on all of these varieties including the White Kidney. The variety, Bird-eye, escaped heavy infection. No

infection was noted on the exotic species, Adsuki, Kulthi, Rice and Moth beans, but occurred to a slight extent on Urd bean (*Phaseolus mungo*), Mung bean (*P. aureus*), Hyacinth bean (*Dolichos lablab*), and White Dutch Case-knife bean (*P. multiflorus*).

Mosaic, which, like the preceding disease, is carried in the seed, occurred rather generally. It was noted as early as May 25 at Indianapolis, and later during the season at Vincennes and Lafayette. In the variety plot above mentioned, mosaic occurred to a greater or less extent on all varieties except Wardwell's Kidney Wax, Red Kidney, Saddleback Wax, Dwarf Horticultural, Robust Pea, Black Valentine, Improved Goddard and Webber Wax. Mosaic also occurred on the Adsuki bean (*Phaseolus angularis*), Urd bean, and Mung bean but not on the Kulthi bean (*Dolichos biflorus*), Rice bean (*Phaseolus calcaratus*), Moth

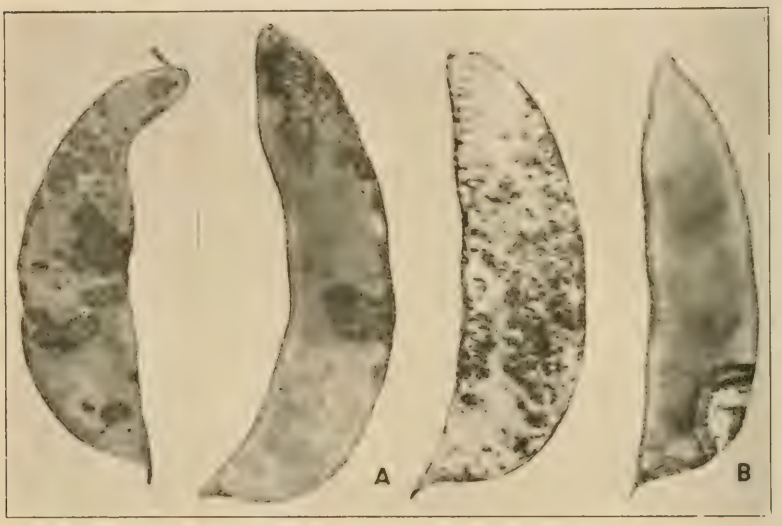

Fig. 3. Lima bean. A. Bacterial blight (3 pods). B. Soil rot (1 pod).

bean (*P. aconitifolius*) and Hyacinth bean. Efforts to cross inoculate beans with soybean mosaic were unsuccessful. Unmistakable evidence of mosaic transmission in the seed of the Adsuki bean was obtained by both field and greenhouse tests.

During the July drouth, R. C. Friesner found a root rot and wilt resembling the Fusarium root rot disease in a garden plot of Kentucky Wonder beans at Indianapolis. In late-planted beans near Lafayette there was considerable fungus injury to the crop of seed owing to the extremely wet weather in the fall. Staining and shrivelling of the seed were the outstanding effects produced.

Lima bean.—A bacterial spotting of the leaves and pods due to *Pseudomonas phaseoli* was commonly noted on both bush and pole varieties in gardens and to a considerable degree on the canning crop in Johnson County at the time of harvest in September (fig. 3A). The causal organism was isolated from pod and leaf lesions.

The lima beans grown for canning purposes are harvested while the pods are green and the seeds immature. A considerable percentage of the beans are culled out on the sorting belts and discarded because of discoloration or decay. Several types of diseased beans were observed. In one type a dark brown or black rot of the cotyledonary tissue predominated. Whether or not this was due in part to bacterial blight infection was not determined. Typical Rhizoctonia soil rot lesions (fig. 3B) were found on certain pods and some of the seed lesions above mentioned may have resulted from this disease. The predominating type of cull was one showing a shallow brown discoloration confined to the testa and cotyledon epidermis. Such seeds were found in older pods that appeared to be affected with a fungous rot and upon incubation a Fusarium developed from these browned beans as well as the rotted pods. The wet weather of September no doubt increased the amount of seed infection of the types represented by these culls.

Mosaic has not been noted to any considerable extent among lima beans, although it occurred in a garden in Lafayette and one case in the greenhouse evidently resulted from seed carriage of the virus. A powdery mildew (possibly *Microsphaera euphorbiae*) became destructive on lima beans grown for experimental purposes in the greenhouse. Reddish brown blotches were produced on the leaves and considerable defoliation resulted. The disease was much more severe on an adjacent row of cowpeas, and also occurred on Kulthi beans and to a less extent on Urd beans. None was noted on Rice and Hyacinth beans, similarly exposed to infection.

Beet.—Leaf-spot caused by *Cercospora beticola* was especially severe this year in the market gardens about Indianapolis. It was observed in July and again in September and at both times was blighting the foliage very generally, causing the beds to present a scorched appearance. On August 5, a number of sugar beet fields were inspected in Adams County and in general only a small amount of leaf-spot was noted. However, in one field, where beets had also been grown the year before, leaf-spot was very destructive and coalescence of the large blackened lesions was killing much of the older foliage in certain areas. It was reported by field men of a beet sugar company that leaf-spot was much worse in one of the sugar beet growing areas in Allen County where crop rotation was not generally practiced by the growers. Lack of crop rotation is evidently very conducive to destructive outbreaks of leaf-spot. Kendrick found leaf-spot causing scorched areas, visible from a distance, in Grant County on September 17, and inspection revealed that the older leaves were killed by the coalescence of the lesions.

Because of unusually hot weather and heavy rains the last of May in Allen County, very heavy losses to the sugar beet growers were caused by damping-off and root rot. A number of fields were visited June 6, and the loss in stand from damping-off and root rot was alarming. In fact some growers had plowed and reseeded their fields. In most fields, however, it was evident that sufficient stand of plants was left to insure a partial crop. Thinning or blocking of the thickly seeded

rows was in progress at this time. The growers reported that a considerable loss of plants from damping-off occurs every year, ordinarily early enough so that by the time of blocking, all affected plants will have disappeared. The peculiar weather of this season, however, produced an excessive amount of the trouble at a much later date than usual so that the affected plants had not yet died at the time of blocking. As a result, it was impossible to detect which plants were healthy and which diseased at the time of blocking the rows and consequently a high percentage of the plants which were left proved to be diseased and later died. The outstanding symptom was a blackening of the cortex of part or all of the root, lack of lateral roots, and a constriction near the ground line. It was evident that many affected plants would recover. Cultural and incubation tests with a number of these diseased seedlings

Fig. 1. A serious sugar beet disease, apparently mosaic in character.

yielded a variety of organisms. It seemed evident that the trouble was primarily climatic and edaphic in origin.

On August 4, a number of beet fields were visited in Adams County and in all fields about two to five per cent of the plants were affected with a very peculiar disease apparently of a mosaic nature. The same trouble was also found by Kendrick in several fields in Grant County on September 17 and is evidently of considerable economic importance. Several types of symptoms were noted. Older leaves were in some cases yellowish, thickened, and strap-shaped, and many were dying prematurely. The younger leaves were tightly rolled backwards longitudinally (fig. 4), often more on one side than the other so as to be curved, were finely crinkled, and frequently showed in transmitted light a network of etiolated veins. This is evidently the same disease described and illustrated by Cunningham (8) in 1899. In some respects the disease resembles curly-top but lacks certain essential symptoms.

Specimens were sent to Carsner at Riverside, Cal., who reported that the disease was not curly-top. The disease does not resemble the mosaic described by Robbins (36) but may be identical with another disease mentioned by him in his account of the mosaic disease. Preliminary attempts to transmit the disease to seedlings by juice inoculation have been unsuccessful.

Crown rot or root rot, caused probably by Rhizoctonia, was noted in a few fields. A Fusarium was also noted in association with some of these rots. One scab lesion was noted. Considerable drouth injury as evidenced by a general premature death of the older leaves was noted in certain fields. In one field deep soil cracks were abundant and in cases where a crack occurred along the same plane as that occupied by the two rows of lateral roots on a beet tap root the effect was often fatal to the plant.

Blackberry.—Anthracnose, caused by *Plectodiscella veneta*, was noted causing yellowish, greasy, translucent leaf lesions on April 18 near Lafayette, and the fungus was cultured from these lesions. A similar leaf-spot and a subsequent shot hole effect were found on wild blackberries in Lawrence County on April 29. Rust occurs to a considerable extent on wild blackberries and often is destructive in plantings. One complaint of rust injury was received from Vanderburgh County. Mains reports that the long-cycled *Gymnoconia interstitialis* occurs in northern Indiana and the short-cycled *Kunkelia nitens* in southern Indiana. In the vicinity of Lafayette both species occur and are indistinguishable macroscopically. Crown gall was found on the cut ends of root segments of the Taylor variety imported from Ohio for use in an experimental planting at Lafayette. Sooty blotch and fly speck (*Leptothyrium pomi* or *Gloeodes pomigena* [7]) has been noted on the canes of both cultivated and wild plants. Leaf-spot, due to *Mycosphaerella rubi*, was found prevalent at Lafayette.

Cabbage.—Yellows, due to *Fusarium conglutinans*, continued to be the worst cabbage disease in Indiana and was severe on the early crop during the hot weather of June and July. The disease was reported from Lake, Marshall, White, Tippecanoe, Clinton, Jay, Marion, Knox, Jackson, Jefferson, Clark, Floyd and Vanderburgh counties, and is apparently well established in all parts of the state. The yellows-resistant Wisconsin Hollander is coming into more general use as a late variety in Lake County. Marion County growers are trying the resistant All-Seasons variety and are also developing resistant strains of earlier varieties.

Owing, perhaps, to the very wet spring, black leg, caused by *Phoma lingam*, was very prevalent and destructive among young plants recently transplanted. Specimens of diseased transplants were received from Miami County in May and on May 20, black leg was found killing many plants in recently planted fields near Indianapolis. In many cases new secondary roots were being produced above the cankers. This disease is primarily a seed-bed trouble and the bulk of infection occurs therein. It is disseminated with diseased transplants and striking evidence of its introduction into Indiana market garden sections was af-

forded this spring. In March a grower in Marshall County received a consignment of cabbage plants from the Piedmont Plant Co., Albany, Georgia, many of which bore black leg cankers near the ground line. Pycnidia containing spores were present in these cankers.

Club-root, caused by *Plasmodiophora brassicae*, has previously been reported from Lake County and was found this year in the muck soils near Goshen. Black leaf spot due to *Alternaria brassicae* was found at Lafayette. Damping-off of seedlings, due to *Sclerotinia libertiana*, was troublesome in a greenhouse near Lafayette in March and a Sclerotinia collar rot of older plants was sent in from Miami County in July.

Cantaloupe.—As usual, the most serious disease of cantaloupes was wilt due to *Bacillus tracheiphilus*. It was noted in Marion and Tippecanoe counties in July and was reported from Marshall and Franklin counties. The peak of the wilt epiphytotic comes rather early in the season and fewer blank spaces will result in the field if enough seed is planted so that there are several plants in each hill and if the thinning process is postponed until after the disease has run its course. It should be remembered that this disease is spread entirely by the striped cucumber beetle (*Diabrotica vittata*), lives over winter in this insect, and does not persist in the soil.

Since most of the good melon soil in Indiana is on the sandy ridges along the rivers and is consequently rather restricted in extent on any one farm, there has been a tendency to grow melons in such fields year after year. This practice has resulted in an increased prevalence of diseases which persist in the soil. In general, watermelons can no longer be grown in such fields because of the Fusarium wilt and, since cantaloupes are not subject to such a disease, this crop has superseded watermelons in many sections. However, failure to rotate the cantaloupe crop very likely is responsible for the increased prevalence of the leaf blight due to *Alternaria brassicae nigrescens* although the disease also occurs to some extent in fields not previously in melons.

Another disease favored by the continual culture of cantaloupes year after year not necessarily in the same fields, but in the same locality is the mosaic disease which persists over winter in perennial weeds (11) and is carried to cantaloupes by insects. Mosaic was noted in Knox, Marion and Tippecanoe counties but was not prevalent. In a field at Lafayette, a Fusarium rot of the fruit (fig. 5), much of which resulted from growth crack infection, caused a 15 per cent loss. A Fusarium rot was also reported by U. S. Bureau of Markets inspectors in two cars from Posey County. Anthracnose (*Colletotrichum lagenarium*) was found on a volunteer plant in September in Morgan County, but was not noted in cantaloupe fields.

Carrot.—Leaf-spot, caused by *Cercospora apii carotae*, was especially prevalent in the Indianapolis market gardens this year, particularly where the Skinner system of irrigation was used. It was noted in July and again in September and in many instances was actually killing the leaves. It was also noted near Goshen in September. Microscopic examination of specimens collected in July showed abundant

sporulation on the lesions on the leaf blades but none on the petiole lesions.

Celery.—The heat of July was favorable to the Fusarium yellows disease which is present in much of the celery soil, but August and September were not as favorable to the disease. It was noted in Indianapolis market gardens where the growers still grow the susceptible Golden Self-blanching variety and near Lafayette. The use of the resistant Easy-Bleaching variety has saved the celery industry near Goshen. Laboratory studies of the temperature relations of this fungus in culture show that it makes practically no growth at 10° C and 35° C, that it grows well at 16° and 20° C, better at 30°, and best at 25° and 27° C. This would indicate that a high soil temperature should aggravate this disease, and previous observations on this disease in the Kalamazoo, Mich., celery marshes in 1914 indicate that such is the case.

As usual, early blight, caused by *Cercospora apii*, was very destructive and was killing much of the older foliage in the celery patches

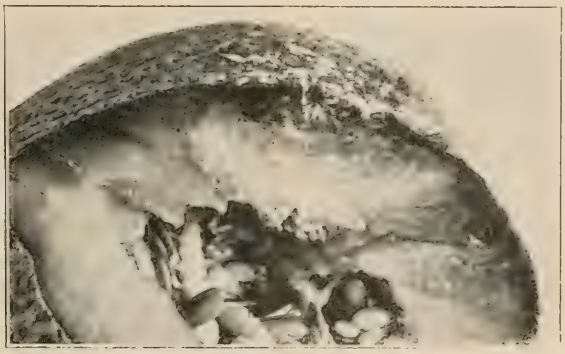

Fig. 5. Fusarium rot of cantaloupe in ripe fruit.

near Indianapolis and Lafayette in July. In a truck garden in Henry County, July 20, this disease appeared to be worse on the Golden Self-blanching variety than on the Easy Bleaching. The Goshen fields were visited on September 22, and in the crop that was then being harvested early blight was so severe as to necessitate stripping off of many leaves that otherwise would have been salable. In many cases this disease was directly responsible for the loss of three or four large stalks per plant. Laboratory studies of the effect of temperature upon the growth of this fungus have shown that very little growth occurred at 10° C and 35° C, and that growth was good between 16° and 30°, with an optimum at 27° C. Spore germination occurred readily in both water and prune decoction at temperatures from 10° to 30° C. *Septoria apii*, the fungus causing late blight, which is less destructive in Indiana than early blight, was found to grow well only between 16° and 27° C. and to grow best at 20° C. Spore germination occurred readily between 16° and 25° C. Thus *Septoria apii* has a lower optimum temperature for growth and a narrower range for vigorous spore germination than is the case

with *Cercospora apii* and this may account for the greater destructiveness of the latter under Indiana conditions.

An unmistakable mosaic disease (fig. 6) was noted in two fields near Indianapolis on September 7 in the Golden Self-blanching variety. In one field numerous scattered cases were observed. The trouble is evidenced by a characteristic mottling, crinkling and extreme distortion of the leaves. This disease has recently been described by Poole.[4]

Cherry.—Burkholder reported that leaf-spot, due to *Coccomyces hiemalis*, was very severe as usual in southern Indiana and that in unsprayed orchards defoliation was very nearly complete by the first of August.

Clover.—Mains reported that the rusts, *Uromyces fallens* on crimson clover and *U. trifolii* on white clover, were not as prevalent as in 1920. Leaf-spot, due to *Cercospora medicaginis*, was found near Indianapolis on July 13. Powdery mildew was conspicuous on clover in many localities during the fall, due largely to the wet weather.

Fig. 6. Celery mosaic. Leaves thickened and greatly distorted.

Root rot troubles with clover have frequently been reported from southern Indiana. Death of the crop in many fields early in the spring was reported from Harrison County and whether this was due to root rot, anthracnose or other causes is not known. In March, specimens of a root rot were received from Owen County and a Fusarium was cultured from a number of roots. This trouble may possibly be identical with a Fusarium root rot recently reported from Ohio (39). Mosaic (12) was noted in Marion, Kosciusko, Orange and Tippecanoe counties, usually on red clover. In Marion County it was noted on sweet clover and at Lafayette on alsike clover. Attempts to transfer this disease to soybeans were unsuccessful. Dodder was reported very bad in clover fields in Tippecanoe County and vicinity. This season seemed especially favorable to dodders and the large yellow patches were noted in abundance on wild vegetation along river banks.

[4] Poole, R. F. Celery mosaic. Phytopathology, *12*, 151-154, 1922.

Corn.—Hoffer reported a loss of about 10 per cent in the corn crop due to root, stalk and ear rots. He has given a very concise explanation of the present understanding of the root and ear rot problem in a current bulletin of the federal Plant Disease Survey (26) in which he shows that the Fusarium root rot is not a specific parasitic trouble comparable to cabbage yellows and tomato wilt but is more or less dependent on predisposition of the plant to infection by certain soil conditions. Ear infection is local and not the result of systemic infection of the plant and seed infection or infestation is important mainly in connection with the vigor of the seedlings and has little direct relation to the occurrence of root rot later. Ear rots due to Fusarium, Penicillium and Diplodia were particularly destructive this year because of the wet fall and the widespread injury by the corn ear worm. Hoffer reported that Diplodia ear rot occurred on as high as 75 per cent of the ears in certain fields. Smut (*Ustilago zeae*) was generally prevalent, especially on sweet corn, but, according to Hoffer, was not as abundant as in 1920 owing to the drouth during the early growing season. One lesion of *Physoderma zeae-maydis* was found by Trost at Lafayette on Early Evergreen sweet corn.

Cowpeas.—The spot disease of cowpeas previously reported as due to a Phyllosticta occurred at Lafayette and has been found to be bacterial in nature. Reddish brown spots on the leaves, stems and pods and constriction of the pods are produced. The disease is seed-borne and in its effect on the pods causes considerable loss in the yield of seed. Leaf-spot caused by *Cercospora cruenta* occurred in the experimental plot mentioned above and also was noted in Knox County. It became severe enough to kill the leaves in some cases. A powdery mildew became very severe in the fall on cowpeas in the greenhouse. Large brown blotches were produced on the leaves and hypocotyls and the plants were defoliated and killed outright. The attack on cowpeas was much more severe than on adjacent rows of lima beans. Perithecia were not found and whether or not this is *Microsphaera euphorbiae* recorded by Fawcett (13) on cowpeas is not known.

Cucumbers.—Wilt caused by *Bacillus tracheiphilus* was the most important disease in the pickle, market garden and greenhouse crops. Gregory reports wilt destructive to the fall crop in greenhouses at Terre Haute. Observation of numerous fields in the vicinity of Plymouth on August 2 showed a loss of three to ten per cent in stand due to wilt. The disease was also found in Marion and Tippecanoe counties and was reported from Allen, Fountain and Fulton counties. Row planting or the hill system with numerous plants in each hill and postponement of final thinning until the peak of the wilt epiphytotic has passed are suggested as palliatives for this disease. Bacterial wilt has been discussed in more detail in connection with cantaloupes.

Mosaic seemed to be less prevalent than usual this year. In the pickle crop near Plymouth, it was noted only on scattered plants on August 2 and seemed to be of late inception. It was noted as early as July 12 near Indianapolis and was severe by September 7. It was very severe in a field near Hammond on August 31 and was noted near

Goshen in September. The relation of weeds to this disease was mentioned in our account of cantaloupe mosaic. It seems probable that the milkweeds, once infected, serve as a perennial source of infection for cucumbers (11), and that this accumulating reservoir of mosaic in the weed flora has driven the pickle-growing industry out of one region after another.

Angular leaf-spot, due to *Bacterium lachrymans,* was found in only one of several pickle fields visited near Plymouth on August 2 and also occurred in a field near Hammond. Anthracnose, due to *Colletotrichum lagenarium,* was found in one of the fields visited near Plymouth and also, later in the season, in fields near Indianapolis and Goshen. The wet weather of this season of course favored anthracnose. It was again present in the greenhouse where it occurred last year and overhead irrigation was undoubtedly responsible for its prevalence.

Eggplant.—Leaf-spot caused by *Phomopsis vexans* was noted on young plants in a market garden near Indianapolis on May 20. A leaf-spot caused by *Septoria lycopersici* was found on a few plants in our experimental greenhouse. *Phytophthora terrestris* caused a rot of eggplant fruits in an experimental garden at Lafayette in September. The fungus had been prevalent on an adjacent plot of tomatoes and very evidently the infection spread from the tomatoes to the eggplants. Wilt was noted near Indianapolis and reported from Logansport. From specimens collected a Sclerotium was isolated.

Goldenseal.—An outbreak of Botrytis blight occurred in early September in Greene County and was probably attributable to the very cloudy wet weather.

Gooseberry.—Anthracnose caused by *Pseudopeziza ribis* was noted in Cass County and leaf-spot caused by *Mycosphaerella grossulariae* was found prevalent near Lafayette in September. A specimen of powdery mildew (*Sphaerotheca mors-uvae*) was sent in from Putnam County in September.

Grape.—Black-rot caused by *Guignardia bidwellii* was exceptionally destructive this season and specimens of fruit infection were sent in with complaints from several localities. P. G. Ewald, county agent of Switzerland County, found fruit infection in June and reported that the Concord variety similarly exposed was free from infection. The disease was reported from Allen, Ripley and Dekalb counties in July and from Lagrange County in September.

Kale.—Yellows caused by *Fusarium conglutinans* occurs to a considerable extent in the Indianapolis market gardens because of the rather general soil infestation of the causal fungus, which also causes cabbage yellows. It was found severe on young plants as early as May 25 and was even more severe in July. Both kale and kohlrabi showed considerable drouth injury in July.

Lettuce.—Downy mildew (*Bremia lactucae*) occurred to a considerable extent in the fall and winter hothouse crops and to a less extent in the spring crops. Preliminary tests of the effect of tempera-

[5] Kendrick, James B. Phytophthora rot of tomato, eggplant and pepper. In Proc. Ind. Acad. Sci., 1922.

ture upon spore germination show that good germination occurs at 4°, 9° and 16° C and practically none at 20° and above. The most prompt germination (within three hours) occurred at 9° C. This indicates that a very low temperature is necessary for infection with this fungus and may explain why it is worse in the winter crops than in the spring crop.

Botrytis rot of the older leaves and stems was found in the spring hothouse crop, and drop due to *Sclerotinia libertiana* occurred rather generally in greenhouses. It was noted in the spring crop and reported very destructive in mid-winter in one Indianapolis greenhouse. A trouble resembling rosette due to Rhizoctonia was noted in the field crop in September.

There is considerable difficulty in the greenhouse crop with a marked stunting of the plants. No root or stem lesions are associated with this trouble and it may be due to the use of a poor quality of soil or to a harmful accumulation of soil salts in the surface layers. Leaching by surface watering and better under drainage should correct the latter condition.

Oats.—Jackson reports that there has been somewhat of an increase in the prevalence of the smuts this season owing to a less consistent practice of seed treatment than has been the case in previous seasons. Gregory reports smut losses varying from one to as high as 35 per cent. Jackson and Mains attribute considerable loss in yield to crown rust (*Puccinia coronata*) in central Indiana and Mains reports that there was a very slight amount of stem rust (*P. graminis*) this year. Hosmer found no stem rust in his surveys made in connection with the barberry eradication work. The hot dry weather of this season was very unfavorable to oats.

Onion.—Gregory found smut caused by *Urocystis cepulae* very destructive in the onion set crop on three farms in Lake County, causing as high as 50 per cent loss, and growers informed him that the disease was present on about twelve other farms in the county. On June 16, Gregory found a light infection of onion smut in a field in Jasper County. Red onions seem to show some resistance to this disease. In control tests with the formaldehyde drip on the seed drill, Gregory reported very favorable results, the yield of graded sets being doubled and the amount of undesirable over-sized bulbs reduced one-half.

Smudge caused by *Colletotrichum circinans* was found causing a rather serious rotting of the outer scales of white sets in storage in March. As many as five outer scales were involved and there was practically 100 per cent infection in the sets examined. These onions were grown on soil that had been continuously cropped to onions for about ten years. The disease was noted to a limited extent in the fall in Fulton County. Botrytis rot was found to a considerable extent in Fulton County in the fall. Its occurrence in the recently harvested crop indicates field infection. Black mold (*Sterigmatocystis niger*) was found abundant in the recently harvested crop in Fulton County in the fall. Harmless infection of pink root, a soil Fusarium disease, was found near Indianapolis on July 12.

Parsnip.—Leaf-spot, caused by *Cercosporella pastinacae*, was found very prevalent in several market gardens near Indianapolis and was also noted near Goshen. As observed September 9, this disease caused a conspicuous mottled or speckled appearance of the upper side of the leaf owing to the yellow color of the very small, thickset, angular, intervenous lesions. On the lower epidermis these lesions presented a dusty or velvety gray surface due to the abundant sporulation of the fungus. As the lesions become older the tissue dies and turns brown and frequently the lesions were so abundant that entire leaves were killed.

Pea.—Bacterial spot of field peas, caused probably by *Bacterium pisi*, was found producing greasy, parchment-like lesions on the leaves and stems in a field in Marion County on May 20.

Peach.—Burkholder reported that leaf curl, due to *Exoascus deformans*, was not as bad as in 1920. He found it destructive in Morgan County and also noted it in Posey County on April 11. It was noted near Lafayette, Vincennes and Bedford in April, and was found rather conspicuous near Peru on May 19. Fruit lesions are shown in figure 7.

Fig. 7. "Birth-mark" fruit lesions of the peach leaf-curl fungus.

Black spot, due to *Bacterium pruni*, was by far the most serious disease of peaches in Knox County and was also found in Dekalb County on August 10. It was particularly severe in Knox County during the early part of this season. On April 28, there was abundant leaf infection and much defoliation had already occurred. A few trees showed very conspicuous blighting of the young shoots of the current season not unlike the twig blight phase of fire-blight on pears. Elongated, blackened cankers had girdled and killed the young twigs. The causal organism was isolated from these blighted twigs and it is likely that this type of attack resulted from bud infection of the previous season. Cankers were not numerous on 1920 wood and usually were located at leaf scars. On June 28, the disease was still prevalent on the foliage and defoliation was still in progress. Very general fruit infection was evident. The disease was somewhat less severe on the trees in the hollows than on the ridges and there was some indication of a partial control from a 1-7-50 Bordeaux spray that had been applied to a few trees on May 29. On October 21, no recent leaf infection was noted and the disease had removed all but a terminal tuft of the younger leaves on each twig. Very few cankers on 1921 wood could be found.

Brown rot, caused by *Sclerotinia cinerea*, was found in Knox County, June 28, on many wounded fruits of an early variety. The fungus was sporulating abundantly at that time. Twig cankers of scab, caused by *Cladosporium carpophilum*, were sent in from Dubois and Greene counties and twig infection was noted in Lawrence, Tippecanoe and Knox counties. Burkholder has found abundant evidence that scab is brought into Indiana on southern-grown nursery stock. A consignment of nursery stock received in Posey County in March was very heavily infested with scab cankers. The fact that certain orchards have the scab disease present and others do not may be explained by the presence or absence of the disease on the original nursery stock. The same condition holds true for black spot and the explanation may be the same.

Root rot caused by *Armillaria mellea* is still present in the orchard in Brown County where it was recorded in 1919, and along with other types of root rot is a serious source of loss in this orchard. Burkholder reported that the root rot situation among peaches very closely parallels that among apples in that the trouble occurs wherever peaches are planted on newly cleared land in the area embracing Brown, Monroe, Greene, Martin, Orange, Lawrence and Jackson counties; and over one-fourth of the peach trees in the state are grown in this area. However, it is not likely that this trouble is all due to the fungus named above. On 1921 twigs the fly speck fungus (*Leptothyrium pomi*) and an occasional colony of sooty blotch (*Gloeodes pomigena*) were noted in Knox County on October 21. Mains reports that the aecial stage of the rust, *Puccinia pruni-spinosae*, is annually prevalent on *Thalictrum dioicum* near Lafayette, but no telial stage on Prunus species has been found.

Pear.—Fire blight, due to *Bacillus amylovorus*, was noted near Indianapolis in May, near Goshen in the fall, and was reported from Hamilton County. In general, fire blight was not severe this season. Black rot due to *Physalospora cydoniae* and sooty blotch (*Gloeodes pomigena*) were noted on pears in the market at Goshen. Frost injury ruined the crop in southern Indiana.

Pepper.—Mosaic was very prevalent in the Indianapolis market gardens and was noted at Lafayette. Conspicuous mottling and "pockmarks" on the fruit were caused by this disease. Sunscald of the fruits was found very destructive in the market gardens on July 12. Kendrick[6] found *Phytophthora terrestris* causing a rot of peppers at Lafayette.

Plum.—Black knot, caused by *Plowrightia morbosa*, became conspicuous in a number of localities this season. It was noted in Miami County and was reported from Marshall, Clinton, Randolph, Hancock, Marion, Monroe, Franklin and Scott counties. Brown rot of the fruit caused by *Sclerotinia cinerea*, was sent in from Marion County. Specimens of plum pockets caused by *Exoascus pruni* were also received this season. Frost injury prevented the set of fruit in southern Indiana.

Potato.—Owing probably to the abatement of the hot weather and the abundant rainfall in August, Fusarium wilt of potatoes was not as

[6] See footnote under eggplant.

prevalent as in previous seasons. However, it was found causing a 50 per cent loss in one field in Kosciusko County and Gregory noted one field in Carroll County on August 29 in which there was 10 per cent wilt infection. In a field in Laporte County planted with seed tubers selected for freedom from wilt-infection, about two per cent was found on August 3. Gregory noted the disease in Floyd, Harrison, Hancock, White and Cass counties, and Gaylord noted it in Porter County. A very little wilt was noted in Elkhart County. Gaylord found vascular discoloration very prevalent in the Irish Cobblers grown in Harrison County this season. Kendrick has found that only about 40 per cent of the tubers showing vascular discoloration yield an organism in cultural tests. In these isolations, a type of Fusarium predominated and in its temperature relations this form resembled *F. oxysporum*. Good growth occurred at 16° and 20°, but was best from 24° to 35°, with a rather distinct optimum at 27° to 30° C.

Gregory reported leaf-roll serious in fields observed in Floyd, Harrison, and Jasper counties and the disease was also noted in Fulton, Kosciusko, and Elkhart counties. Mosaic may be detected with more certainty than leaf-roll under field conditions and striking cases were observed in Early Ohios in Marion County on May 20, and in Lake County in Early Ohios and Rurals as well. Gregory noted mosaic in Floyd and Dekalb counties.

During the winter and early spring, Kendrick tested in the greenhouse, single-eye seed pieces from samples of seed stock sent in from several potato-growing sections in the state in order to ascertain to what extent mosaic and leaf-roll might be present in home-grown seed. Blodgett (5) at Cornell found that these two diseases showed up conspicuously under greenhouse conditions and this method of analysis is particularly useful in Indiana because the symptoms of these diseases may not be at all clear cut under field conditions. Out of 20 lots of seed tubers from twelve counties, nine lots, representing Hancock, Fulton, Whitley, Floyd, Clark, St. Joseph, Laporte and Lake counties, showed leaf-roll and four of these, both mosaic and leaf-roll. The latter four were from Hancock, Whitley, Clark and Lake counties, and the percentages of mosaic were low. In addition one lot of Early Ohio seed from Tippecanoe County showed 95 per cent mosaic. The highest percentages of leaf-roll were in Bull Moose potatoes from Floyd and Clark counties, Carmens from Laporte County, Early Ohios from Tippecanoe County and Rurals from Lake County. These results show that leaf-roll was rather prevalent in the 1920 crop in Indiana and the occurrence of 81 per cent and 98 per cent leaf-roll in two large lots of Rurals from Lake County and 12 per cent mosaic in one of these lots indicates that leaf-roll and, to a less extent, mosaic are responsible in part for the decline in potato yields in Lake County mentioned in last year's report (17). While leaf-roll may be readily detected under field conditions in the cooler northern states, field row tests at Lafayette and Hammond in 1921 with healthy and leaf-roll seed tubers of the Rural variety showed that it was practically impossible to detect leaf-roll under the field conditions existing in those localities. However, the disease reduced

the yield about 40 per cent and must be recognized as an extremely important loss-producing factor in this state. The desirability of obtaining seed potatoes free from leaf-roll and mosaic is perfectly obvious.

In the late crop, early blight, caused by *Alternaria solani*, was exceptionally prevalent this season. Gaylord reported that it was worse in the late crop than he had ever noted in his experience and records its presence in 12 counties. Gregory reported that early blight was epidemic in Floyd and Harrison counties. In some fields the disease appeared to be responsible for the yellowing and premature death of

Fig. 8. Potato diseases. A and B. Effect of Rhizoctonia on sprouts. C. Advanced stage of black leg caused by *Bacillus phytophthorus*.

many plants. Early blight was prevalent during the entire season in fields under observation near Lafayette and Hammond.

Gregory found one tuber from the 1920 crop of a grower near New Albany which was affected with late blight rot, due to *Phytophthora infestans*. This is apparently the first specimen record of this disease for the state. Gregory was unable to find any trace of the disease in the 1921 crop on the same farm. Although the extremely wet weather of August and September should have favored the occurrence of late blight, it was not found in any of the numerous fields examined. On the older stems of the early crop, sunken lesions located just below the points of attachment of the leaves were found very abundant. With these lesions, a fungus of the Gloeosporium type was commonly asso-

ciated and it is likely that this is identical with the potato anthracnose recently reported from Ohio (9).

Inasmuch as black leg (fig. 8C), caused by *Bacillus phytophthorus*, is one of the cool-climate diseases, it was not surprising to find it occurring to some extent in the early market garden crop near Indianapolis. On May 20 the disease was causing characteristic symptoms on about one per cent of the plants in certain of these fields which, it appeared, had been planted with home-grown seed. In these same fields there was a considerable loss due to the destructive effect of *Rhizoctonia solani* on the young shoots (fig. 8, A and B). The occurrence of numerous blanks in the rows was attributable to this disease and a prevalent stunting of the plants was found to be due to the killing of the main shoot by a Rhizoctonia lesion below the ground line and the subsequent development of a lateral shoot from a point below the canker. Typical, brown, Rhizoctonia lesions were frequently present on these secondary shoots and also on the roots. This destructive activity of Rhizoctonia early in the spring under Indiana conditions is exactly what should be expected in the light of Richard's (35) determination of the low soil temperature optimum (18° C) for the parasitic activities of this organism upon the young shoots. The extremely destructive effect of the disease, especially on the young shoots, emphasizes the necessity of disinfection of the seed for the early crop. The black scurf stage of this disease on tubers was generally prevalent throughout the state.

Scab, caused by *Actinomyces scabies*, is state-wide in its occurrence. In a field near Lafayette much deep scab, such as Coons has attributed to the secondary action of mites in the scab lesions, was noted. In another field there was a very high incidence of the early stage of the so-called russet scab. These lesions were small shallow rounded spots of blackened tissue which later may crack and check and produce the roughened russet scab appearance.

Owing to the excessive rains, the tubers of the late crop very frequently showed extreme cases of enlarged lenticels. This condition was common in low ground in one field observed near Lafayette. A preliminary test indicates that the water loss during four months storage from tubers with enlarged lenticels is 17 per cent more rapid than in the case of normal tubers.

A grower in Franklin County found about 50 per cent of his crop of Early Six Weeks potatoes affected with internal brown spot. In a highly productive muck field in Fulton County planted to a late crop of Rurals, overgrown tubers and second growth knobs were of very frequent occurrence. Sunburn or greening occurred to a considerable extent this season because the soil was frequently washed away from the upper tubers thus exposing them to the sun. In the muck field mentioned above there was also a rather high percentage of tuber rot, some due to Fusarium, some apparently to bacteria. The Fusarium rot was of a peculiar type, since it was usually associated with the death of rather extensive cortical areas. The bacterial rot was more or less confined to the central tissues of the overgrown tubers.

Rotting of the seed pieces in the soil was the most important source

of loss in the late crop and resulted in very poor stands in central Indiana. Certain fields were almost a total loss because of this trouble. According to Gaylord's observations, this failure occurred mainly in potatoes planted about the middle of June and is attributed by him to high soil temperature. He found that the loss in stand was very much less in the fields which were rolled after the seed was planted.

Quince.—Heavy spotting of the fruit due to *Fabraea maculata* was noted in Lafayette.

Radish.—Black-root, caused by *Rheosporangium aphanidermatum*, was a very serious trouble in the icicle varieties in the early market garden crops. It was noted near Indianapolis in April and May and was prevalent in gardens in Lafayette in May. It is not a factor in the midsummer crop, but may occur in the fall. In a variety test sown by Brown on August 20, the disease occurred in the fall on the varieties Early Long Scarlet, Early Vienna and Cincinnati Market. By the agar plate method a fungus resembling *R. aphanidermatum* was isolated from diseased roots.

Downy mildew (*Peronospora parasitica*) was found doing considerable damage in beds of small red radishes in an Indianapolis market garden on April 27. The leaves were thickly spotted with small, irregularly lobed, sharply defined, black lesions (fig. 9A) bearing sporophores of the fungus on the lower side. On the upper portions of many of the roots were small, sunken, black lesions caused by the same fungus (fig. 9E). Under these root lesions there was in some cases some blackening of the tissue indicating that the fungus had penetrated to a considerable extent. Under damp chamber conditions in the refrigerator, sporulation of Peronospora occurred on these surface root lesions and on the cut surfaces of the blackened root tissue. Microscopic examination showed abundant haustoria within the host cells. The occurrence of Peronospora in turnip roots has been previously recorded (15). The occurrence of Peronospora in red radish roots was noted by a German observer (4) in 1899, however, and in black or summer radishes by another (40) in 1908. On May 25, leaf lesions similar to those described above were noted on older plants on another farm and blackened petiole and stem lesions were also noted. There was extensive blackening of the pith of these seed stems (fig. 9C) due to Peronospora infection. In another field, more recent foliage infection on icicle and white globe radishes was abundant, but in this case the lesions were the typical angular, intervenous areas (fig. 9B), yellowish above and covered with a white velvety mass of sporophores below.

White rust (*Cystopus candidus*) occurred in the greenhouse crop near Lafayette in the early spring and was found abundant in the Indianapolis market gardens in May. It was noted in abundance on a row of seed radishes in a Lafayette market garden on June 28. Radish seed pods infected with both downy mildew (fig. 9D) and white rust were collected in 1920 (17, p. 201) and a considerable quantity of seed from these pods was planted in the greenhouse but no evidence of seed transmission of either of these diseases was obtained.

Raspberry.—Anthracnose, caused by *Plectodiscella veneta*, remains the worst disease of the black raspberry in Indiana. It was reported

destructive in Lake, Laporte, Noble, White, Carroll and Miami counties. New infection was found near Lafayette as early as April 18. Spur

Fig. 9. *Peronospora parasitica* on radish. A. Blackened leaf lesions. B. Intervenous leaf lesions. C. Longitudinal section of seed stem showing blackening of pith. D. Blackened lesions on seed pod. E. Blackened root lesions on red varieties.

blight of red raspberry caused by *Mycosphaerella rubina* was found in St. Joseph County on June 9 and in Dekalb County on July 15. Leaf-spot caused by *Mycosphaerella rubi* was noted near Lafayette on July

7. Crown gall on raspberry plants was sent in from Clark, Putnam and Noble counties.

Rhubarb.—Leaf-spot, attributed to *Ascochyta rhei*, was found prevalent in the Indianapolis market gardens in May and was noted in July near Lafayette.

Rye.—Anthracnose, due to *Colletotrichum cereale*, caused very heavy losses in rye this year. Specimens were received from a grower in Lagrange County on June 14 showing that affected plants were stunted and were dying prematurely. The heads were light colored and the grain was not filled out. There was some anthracnose infection of the heads causing the portions above the point of infection to dry out, but most of the infection occurred at the lower nodes, on the first internode and on the roots. These lesions bore setose, sporulating acervuli. The grower reported that in a seven acre field about one-third of the plants were thus affected, that in an adjacent rye field planted two weeks later, only a few dead plants had appeared, and that, in another adjacent rye field planted one month later than the first field, many dead plants were visible in the portion adjacent to the first field.

On June 18, Kendrick found anthracnose causing heavy losses near Wanatah. In one 50 acre field, 40 to 60 per cent of the plants were dead and in another of 60 acres, 5 to 10 per cent of the plants were dead. Gregory found the disease severe in Perry County on June 20, and reported one field practically ruined and a similar occurrence was reported from Switzerland County. Mains observed the disease in Lawrence County. Jackson found a destructive foot-rot of rye which was not due to anthracnose in a field in Stark County on June 21. Among the several types of fungi isolated from root segments and lower nodes was an orange-yellow type of Sclerotium. As has been previously pointed out, the mild open winter and warm, wet spring probably favored anthracnose and foot-rot of rye.

Mains reported that leaf rust (*Puccinia dispersa*) was prevalent this season and considerable loss was attributed to its attack. Hosmer found portions of two rye fields, one in Steuben, the other in Lagrange County, ruined by stem rust (*P. graminis*), and in both cases barberry bushes were found near by. Ergot was reported from Switzerland County. Two heads of the rare loose smut were found in Kosciusko County.

Soybean.—Bacterial blight caused by *Bacterium glycineum* is carried with the seed and, like bean blight, is practically co-existent with the crop. The disease occurred in fields near Lafayette and was reported from Greene County. The causal organism has been studied in culture and found to be the non-chromogenic strain of *Bact. glycineum* (29).

Mosaic (22) was found to a limited extent. Attempts to infect field beans with soybean mosaic were unsuccessful, as were also attempts to infect soybeans with mosaic from field beans, from Adsuki bean, and from red clover. A spotting of the older leaves of the varieties Black Eyebrow, Dunfield and Ito San with which a Macrosporium was associated was noted at Lafayette. An objectionable lavender staining of the seeds of certain varieties was found to be due to fungus invasion

and a Fusarium was isolated from the few seeds that were plated out. This trouble was probably attributable to the wet weather.

Spinach.—Downy mildew (*Peronospora effusa*) was found very destructive in two beds of spinach in a greenhouse at Lafayette on March 15. Large areas on the leaves were covered with the gray coating of sporophores and spores and the older leaves were dying from the effects of the disease. Infected leaves were, of course, unsalable, and the disease caused a considerable loss to this grower. In spore germination tests it was determined that temperatures of 4° to 27° C permitted germination, but that only a low percentage germinated at temperatures of 20 and above, while prompt and vigorous germination occurred at 4°, 9° and 16° C. The temperature of 9° seemed to be the optimum for germination while 16 seemed more favorable to subsequent growth of the germ tube.

In a plot of spinach grown under Skinner irrigation in a market garden at Lafayette, about 50 per cent of the plants were found affected with a destructive crown rot on June 21. The plants were of a marketable size at this time and the loss was great. The affected tissue of the recently affected stems and petiole bases was watersoaked and dark green. From diseased plants, a very rapid-growing Phytophthora species was isolated. Spinach blight or mosaic was noted near Goshen on September 22. Nematode root-knot was also noted in the same region.

Squash.—Oval, sunken lesions resembling anthracnose were found on small white squashes in the local market on February 7. The fungus isolated proved to be a Gloeosporium species not identical with the cucurbit anthracnose fungus. In pure culture this fungus was found to grow fairly well at 9° and 16° C, and more vigorously between 20° and 35°, with a fairly distinct optimum at 27°.

Strawberry.—Leaf-spot caused by *Mycosphaerella fragariae* was rather severe this season near Lafayette. The disease was noted in Lake county and was reported from Clark and Kosciusko counties. Lesions bearing an abundance of viable conidia were found on green overwintered leaves in a garden near Lafayette on April 19.

Sweet Potato.—Black rot, caused by *Ceratostomella fimbriata* was the cause of storage loss in the 1920 crop in Jay County and badly rotted roots were received from that county on April 29. W. J. Piggott reported the disease prevalent in the 1921 crop in Knox County, and it was noted by Gregory in Floyd and Tippecanoe counties.

Fusarium stem-rot or wilt was noted in the Indianapolis market gardens on July 12, and at Vincennes on June 28. Gregory reports the disease destructive in Floyd County. A complaint of serious difficulty due to this disease was received from a grower in Boone County and growers in Carroll County reported this disease severe on the Yellow Jersey variety but not on the White Yams.

Scurf, caused by *Monilochaetes infuscans*, was sent in from Jay County on stored roots of the 1920 crop and also caused a very bad discoloration of Yellow Jerseys grown at Lafayette from seed secured from Vincennes. Specimens of Fusarium surface rot were sent in from Union County on Sept. 10, and a Fusarium was isolated from the lesions. The same roots were also affected with a very objectionable trouble ex-

actly resembling internal brown spot of the Irish potato. Numerous areas of corky brown tissues were scattered throughout the flesh of the roots. Attempts to isolate an organism from the lesions were unsuccessful.

Tobacco.—Angular leaf-spot (14), caused by *Bacterium angulatum*, was very destructive in Spencer County this year and was worse in 1920, according to the grower who sent in the specimens and who estimated that the crop was damaged to the extent of fifty per cent by this disease in 1920. As a result of this experience the growers harvested earlier in 1921 to avoid the heavy loss due to this disease. The disease was identified by F. D. Fromme.

Tomato.—Owing perhaps to the excessive rainfall in the spring and late summer, leaf-spot, caused by *Septoria lycopersici*, was much worse than usual in both market garden and canning crops. The disease was noted at Vincennes as early as June 29, and on early tomatoes in a market garden near Kokomo on July 2. The plants for the latter had been grown in a greenhouse that was also used for a hothouse tomato crop, and thus were undoubtedly exposed to infection. At this early date, practically no leaf-spot was evident in the canning crop fields in that region. On July 12, the disease was noted in a number of market gardens about Indianapolis and was especially destructive on staked tomatoes under Skinner irrigation and in a greenhouse where overhead watering was practiced. On July 21, leaf-spot was found to be rather worse than was to be expected at this date in a number of canning crop fields in Marion County. Late in the season the disease became very destructive in the canning crop, as well as the market gardens and caused very general premature defoliation. It was observed in severe form near Indianapolis, Greenwood, Whiteland, and Marion in September.

Considerable evidence was obtained which corroborates the belief that leaf-spot is primarily of plant-bed origin except in cases where crop rotation is not practiced. For instance, leaf-spot lesions were noted on purchased transplants that a grower was setting out on June 1 near Hammond, and later the disease became severe on these plants. At Lafayette no leaf-spot occurred in the plant-beds and none appeared in the fields planted from these beds. Remnant tomato plants are often left to grow during the season in the plant-beds and in two cases observed, one near Indianapolis, on July 13, and one in Johnson County on July 16, leaf-spot was present on these old plants. Leaf-spot may also occur on other plants in these beds since Norton (31) in 1917 found that the tomato Septoria would infect eggplant, potato, and horse nettle, and Beach (3) corroborated these results in 1919. Pritchard and Porte (33) in 1921 also report horse nettle susceptible. By means of remnant tomato plants and other hosts the volume of infective material in the plant-bed soil may be augmented each summer. It is of primary importance in leaf-spot control that plant-bed rotation and sanitation be practiced. By sanitation is meant the destruction of all remnant tomato plants and susceptible weeds in and near the beds and the precaution not to use such soil for eggplants or potatoes.

The extreme heat of June and July was very favorable to the wilt

disease, caused by *Fusarium lycopersici*. The disease was found as early as May 25 in hothouses near Indianapolis and by July 12 it was very destructive. One grower had replaced the soil of his wilt-infested house and another moved his house to avoid using the old wilt-infested soil. While both secured a good crop, yet in both cases scattered cases of wilt occurred. By July 12 wilt was also severe in the market garden field crop and in one field that had been in tomatoes several consecutive seasons there was a fifty per cent incidence of the disease. Wilt was also found destructive in a hothouse at Vincennes on June 28 and there was evidence of spread of the disease to several other houses with infected transplants. It is, of course, to be recognized that any means by which soil from a wilt-infested hothouse is carried to a house where none of the disease has occurred may introduce the disease. In experimental fields at Lafayette, wilt was first noted on June 21, and by the middle of July there was a scattered infection involving about two per cent of the stand. The danger of plant-bed soil infestation as a source of this disease was clearly demonstrated by the discovery of two remnant tomato plants affected with wilt in a plant-bed in Johnson County on Sept. 16. This further emphasizes the necessity of keeping plant-beds free from tomato plants during the summer since wilt-infected plants increase the volume of infective material in the soil.

The outstanding feature of the wilt situation this year was the abundant and conclusive evidence of the introduction of this disease into canning crop fields with southern-grown transplants, a danger which has been previously pointed out (18). For a considerable number of growers this evidence was obtained at a high cost. It is likely that in several localities southern-grown plants will no longer be acceptable. On June 30, thirteen fields were inspected near Whiteland, in 12 of which Georgia plants had been used. Wilt was already prevalent among the Georgia plants in every one of the 12 fields and none was noted in the one field planted entirely with home-grown plants. In fact, in fields where both Georgia and home-grown plants had been used, the Georgia plants could be located at once by the abundant wilt infection. Somewhat similar observations were made near Kokomo on July 2. Wilt was present in 12 out of 21 fields examined and Georgia plants were used in five of these 12 fields, and Louisiana plants in 3. The disease was severe in four of the five fields of Georgia plants. On July 20, wilt was found present in eight out of eleven fields near Greenfield and was severe in five of these fields, all of which contained Georgia plants. And again, in fields containing both home-grown and Georgia plants, the disease was confined to the latter. In a number of fields near Indianapolis containing Louisiana plants there was evidence that about two per cent of the Louisiana transplants had been infected. In the Indianapolis territory, however, there is also considerable soil infestation with the wilt fungus. As a basis for comparison it is of interest that, in four fields near Southport comprising about 60 acres and planted entirely with home-grown plants, no cases of wilt were found on July 13.

To summarize these field observations, it is worthy of note that wilt was already severe in 26 of the 76 fields examined before July 22

and that 23 of these 26 fields contained southern-grown plants. The source of the plants in the remaining three could not be determined. In numerous instances the southern plants were a total failure and had to be replaced with home-grown plants. The loss in time and labor to many growers was in itself very discouraging. The loss and inconvenience to the canners who purchased southern-grown plants were serious factors. In addition to the instances above mentioned, canners in Delaware, Dubois, Madison, and Grant counties reported similar losses in southern plants. In one case reported, three acres on one side of a field were planted with Indiana plants and six acres on the other side with Georgia plants and wilt was severe among the Georgia plants while none appeared in the home-grown plants. The really alarming feature of this situation is, of course, the permanent infestation of more and more of our Indiana tomato soils with the wilt fungus.

Mosaic was noted in a greenhouse in Lafayette in March and in the Indianapolis hothouses in May. It was found in a market garden near Vincennes on June 28, in a garden at Lafayette on July 6, and in the market gardens near Indianapolis on July 12. The disease was not, however, as prevalent in the market gardens at this date as in the canning crop fields, but later became very general in the gardens. In 30 acres of tomatoes examined near Paoli on June 29, only one mosaic plant was found. Canning crop fields in Washington, Johnson, Howard, Tipton, Marion, and Hancock counties were examined between June 29 and July 21 and mosaic was found in 55 out of 76 fields. On July 13, a tomato plant with six shoots showing extreme mosaic and one shoot apparently normal was found and several similar cases were noted in the same field.

Mosaic has been particularly prevalent in central Indiana and the reason for this condition has been established and reported at some length in another paper (24). In brief, it has been found that the mosaic disease crosses very generally from tomatoes to certain perennial weeds related to the tomato and, once infected, such weeds send up diseased shoots year after year. Four common Indiana weeds are thus involved, *Physalis subglabrata*, *P. virginiana*, *P. heterophylla* and *Solanum carolinense*, and of these the first two are particularly abundant in the fields of the corn belt in this state and are by far the most important carriers of mosaic. These weeds, as they become infected, constitute a perennial source of infection. Mosaic has been found in abundance on the Physalis plants in fields previously in tomatoes. As more and more new fields are used for tomatoes and the perennial weed flora becomes infected with mosaic, it is only a matter of time before all of the tomato growing regions will become generally and permanently infested with the disease. However, as the situation is understood at present, the greatest immediate danger seems to lie in the presence of mosaic weeds in and near tomato seed-beds and plant-beds, since these weeds serve as early sources of mosaic infection for the tomato plants. In a field survey, unmistakable evidence of the plant-bed origin of mosaic was obtained. As a mosaic control measure it is very necessary that tomato plant-beds be kept free from weeds and remnant tomato plants all summer and that a determined effort be made to eradicate all weed

hosts from the vicinity of the beds. A number of tomato varieties were inoculated with mosaic at Lafayette and all proved susceptible. Peculiar, elevated or embossed, brown fruit lesions were observed on badly diseased plants, accompanied by outright blighting of the young shoots. Such severe symptoms are suggestive of certain types of responses on the part of the host in the case of cucumber mosaic.

Our description of the organism which causes bacterial spot under the name of *Bacterium exitiosum* was antedated by Miss Doidge (10) in Transvaal and as a result the name of the causal organism is *Bacterium vesicatorium*. As a result of our recommendations (21) a considerable amount of the tomato seed used for the canning crop was treated for the control of this disease. The effectiveness of this operation was not carefully checked, but in one region (Jefferson County) where treated seed was used, careful scrutiny of the canning factory sorting belt for several hours on Sept. 8 revealed only three cases of bacterial spot on the fruit. In a Johnson County factory drawing from an acreage planted largely with treated seed, a small amount of bacterial spot was noted on the belt at occasional intervals, but as compared with previous years, the tomatoes were relatively free from the disease. On the other hand, the disease was prevalent as early as July 13 in several fields on plants grown from untreated seed. Leaf, stem, pedicel, and calyx lesions were abundant. Among the 76 fields visited early in the season, bacterial spot was found in ten, and in six of these the plants were known not to have been grown from treated seed. In general the disease made an early appearance this year. Rather severe foliage infection and distortion of the young growing parts was noted in three out of 21 fields near Kokomo on July 2. However, southern-grown plants were used in these fields. As a result of inoculation tests, it has been found that insect wounds are not necessary to permit fruit infection and that the characteristic fruit lesion is the result of very early infection probably through some natural break in the epidermis. Although infection has been readily obtained through stink-bug punctures, the resulting lesions are not typical.

Early blight, caused by *Alternaria solani*, was found rather severe on the foliage of staked Bonny Best tomatoes in Indianapolis market gardens on July 12. Early blight seems to be more prevalent in the canning crop in southern Indiana than in the central part of the state. Late in the season a spotting of the small green fruits remaining on the vines was observed in 1920 and again this year, and these lesions are probably attributable to the early blight fungus. These lesions in no way resemble nailhead spot nor bacterial spot. The presence of the elongated, blackened early blight lesions on the stems of young transplants and the possible later effect of these lesions upon the plants in the field was noted in our 1919 report (16). A destructive outbreak of a very similar collar rot was reported in a field near Greenfield on July 6. This field was planted with home-grown plants of which about fifteen per cent were weakened and stunted by these stem cankers. The same trouble was also noted to a less extent in one other field in the same locality. Spores of the *Alternaria solani* type were found on these cankers but there was no foliage infection on the plants. It is be-

lieved, however, that this collar rot is attributable to the early blight fungus and is identical with the trouble described as foot-rot by Rosenbaum (37) in 1920 and later as collar rot, by Pritchard and Porte (34) in 1921. It is evident that transplants showing these stem lesions should not be set in the fields.

Leaf mold caused by *Cladosporium fulvum* was, as usual, very destructive in the greenhouse crop and was noted in many houses near Indianapolis on July 12. Observation had led to a supposition that this disease was favored by high temperatures but it was found that the fungus grew well in pure culture between 16° and 25° C and very slowly at 30° and that spores were produced at all temperatures between 9° and 30°, inclusive. Spore germination in water or in prune juice occurred at temperatures from 10° to 35°, inclusive, and very readily between 16° and 30° with an optimum for germ tube development at 25° C. These temperature ranges are somewhat wider than those reported by Makemson (30). The spores are easily detached and carried by air currents since abundant secondary infection occurred in the Petri cultures.

Anthracnose of the fruit caused by *Gloeosporium phomoides* was somewhat more prevalent than usual in the canning crop and was present to a serious extent on the sorting belts of factories in Jefferson, Johnson, and Marion counties early in September. It was also noted in the field in Johnson County on Sept. 16. In a variety planting at Lafayette this disease became rather conspicuous on the Yellow Plum variety late in August. In tests with the fungus in pure culture it was found to have no sharp temperature limitations. It grew fairly rapidly at temperatures from 9° to 35° C with somewhat of an optimum at about 27° and a surprising tolerance for temperatures as high as 35°. The original source of field infection in the case of this disease remains unknown since foliage infection does not seem to occur.

In an experimental plot at Lafayette a destructive epidemic of buckeye rot due to *Phytophthora terrestris* occurred during September[7]. The plants were grown in a rather low place and the prevalence and spread of this fungus are attributed to the heavy rains and consequent surface flooding. A high percentage of the fruit became infected. It was evident that wounds were unnecessary for fruit invasion, and that immature fruits were highly susceptible.

The non-parasitic blossom-end rot occurred to a serious extent in the early market garden crop as noted about Indianapolis on July 12, but was much less destructive in the canning crop than in 1920, due supposedly to the rainy weather of August and September. Probably for the same reason the non-parasitic growth-crack trouble was much worse than usual in the canning crop. It was found very severe in September in the stock observed in several canning factories. Cat-face was also present to a limited extent in the canning crop. Sun-scald was rather destructive in the market garden crop during the July drouth and was not necessarily associated with Septoria defoliation. Kendrick noted sun-scald rather prevalent in the canning crop in Grant County

[7] See footnote under eggplant.

in September where there was considerable defoliation due to Septoria leaf-spot.

As a result of the very prevalent growth-crack and corn ear worm injury to the fruit combined with the frequent rains during the picking season, fruit rots were very prevalent this season. In 1920, a row of southern-grown plants infected with nematode root-knot were grown in an experimental plot at Lafayette and in 1921 tomatoes were grown in the same soil. The development of a few galls on the roots of the 1921 crop proved that some of the nematodes had withstood the winter. The persistence of these nematodes in the soil under Indiana conditions justifies our previous warning against the use of infested transplants.

A number of non-parasitic injuries and diseases were noted among tomato plants. The field trouble known as hollow-stem wilt was reported from Madison County during the July drouth. An upward roll-

Fig. 10. Turnip yellows. Typical one-sided effect of the disease: one side of plant affected worse: one-half of central leaf affected worse, resulting in curvature, asymmetry, and yellowing of the stunted side.

ing of the leaves called leaf-roll occurs generally in staked tomatoes in market gardens and hothouses. Güssow (25) and others have attributed this trouble to excessive pruning of the plants. In the spring the tomato seedlings in certain sections of a greenhouse bench at Lafayette showed considerable scalding of the foliage. On days of bright sunshine, it was noted that the location of the injured plants coincided rather closely with strips of intense light which were found to be due to the focusing of the sun's rays by the slight cylindrical curvature of certain panes of glass in the roof.

Turnip.—Yellows caused by *Fusarium conglutinans* was found very serious in a market garden near Lafayette on June 4 where cabbage yellows had occurred before. Many plants were affected and typical symptoms were displayed, such as the one-sided yellowing and subsequent curvature of the leaves, death of the leaves on one side of the plant (fig. 10), general stunting of the whole plant, and a brown dis-

coloration of the xylem tissue in the roots. Upon incubation in a damp chamber, grayish mycelium bearing abundant Fusarium spores developed from the vascular elements in the cut ends of roots and petioles.

A rather destructive Alternaria leaf-spot was found in a patch of turnips on muck soil near Goshen on Sept. 22. Whether or not this was due to *Alternaria brassicae* is not known. A powdery mildew was noted on turnips near Goshen, but no perithecial stage was observed. The mosaic disease described last year (23) was noted at Lafayette on July 22, and was found causing considerable damage in a patch near Goshen on Sept. 22. As a result of the stunting effect of the disease, the roots of many of the mosaic plants were small and worthless. As Schultz (38) has shown, mustard is also subject to this mosaic disease and mosaic was noted on mustard near Indianapolis on May 25.

Watermelon.—Wilt, caused by *Fusarium niveum*, was noted at Vincennes on June 28, and in Tippecanoe County on July 19. This disease remains as one of the limiting factors in watermelon growing in Indiana and, as was pointed out in the 1919 report, much of the suitable watermelon soil has become infested with the fungus. It seems probable that this wilt situation in Indiana is due to the fact, previously mentioned, that the good melon soils are confined to the sand ridges along the rivers and that consequently, on any one farm, there is not very much soil suitable for melons. This condition has resulted in a failure to practice a long time crop rotation which would prevent the accumulation of a soil pathogene. It is largely due to crop rotation that watermelons can be continuously produced in the southern states. The wet weather of late summer favored the development of anthracnose due to *Colletotrichum lagenarium* and serious spotting of the fruits was noted very generally in the local markets. Destructive leaf and stem infection was reported from St. Joseph County on Sept. 29. The non-parasitic blossom-end rot which is usually followed by infection with rot-producing fungi, was reported by one grower in Morgan County late in September.

Wheat.—Gregory reported the prevalence of loose smut (*Ustilago tritici*) in southern Indiana early in June. He noted from four to ten per cent infection in fields in Shelby County, as high as 25 per cent in fields in Rush County planted with untreated seed, and five per cent in one field in Posey County which was planted with grain descending from seed treated in 1919. Loose smut was noted in Lake County on June 1 and in Allen County on June 6, and was sent in from Spencer County. The hot water seed treatment at central treating plants is giving excellent control according to reports received from a considerable number of counties. Stinking smut (*Tilletia foetans*) was noted to a very limited extent in a field in Elkhart County by Gregory and in a field in Tippecanoe County by Jackson.

Hosmer found that stem rust (*Puccinia graminis*) occurred in a destructive form only in the vicinity of barberry bushes, although there was a very light infection in wheat throughout the state, which increased in amount toward the south, according to Jackson. Stem rust was noted in Tippecanoe County and was sent in from Jay County, and Hosmer noted small amounts in Harrison and Franklin counties. The latter observer found wheat fields practically ruined by stem rust near

barberries in LaGrange, Steuben, and DeKalb counties. In DeKalb County, ten acres of wheat across the road from a heavily infected barberry bush were ruined and other fields nearby were badly injured. Wild barberries were found on twelve farms in this county and in every case wheat and rye fields near the barberries were badly rusted.

Leaf rust (*Puccinia triticina*), which is frequently mistaken by growers for stem rust, occurred in epidemic form in southern Indiana this year, and according to Jackson this was the worst outbreak of leaf rust during the last five years. Gregory noted extremely heavy infection in Gibson County and other points in southern Indiana early in June and reports of serious damage were received from Dubois, Vigo, and Jay counties. According to Mains, leaf rust obtained an earlier start than usual, was somewhat worse on spring wheat than on winter wheat, and outside of the barberry areas was much more important than stem rust. Mains and Jackson agreed that very material reductions in yield was to be attributed to leaf rust this year partly because of the extreme severity of the attack itself, and partly because of the fact that the numerous leaf-rust lesions rendered the plants much more susceptible to serious drouth injury during the hot dry weather of late May and June. Mains reported losses as high as fifty per cent in certain fields, and a seven per cent reduction in yield for the state as a result of this disease.

Scab caused by *Gibberella saubinetii* made a late appearance and was not very prevalent this year, although it was slightly more abundant than in 1920. Gregory noted very little of this disease. Mains noted only a small amount near Bedford, Lafayette and Wanatah. A trace was noted in Hancock County, and specimens were received from Marion and Putnam counties.

Rosette occurred only in the experimental field near Wanatah, but its ability to persist through one season without a susceptible crop and to attack the susceptible wheat variety again the third season was demonstrated. The other infested fields were planted with resistant wheat varieties and none of the disease was found. What had every appearance of being the true Australian "take-all" disease occurred in two fields on a farm in Knox County. Jackson examined the fields and found the affected plants stunted and the heads not filled out. This condition occurred in patches and in scattered individual plants. A black layer of mycelium was found about the bases of the stems under the lower sheaths and the roots showed evidence of infection. Jackson found characteristic asci and ascospores of *Ophiobolus graminis* associated with this disease.

Forest and Shade Trees.—Burkholder has found great difficulty with evergreens and other trees planted for ornamental purposes in the northwestern part of the state because of sunscald and winter injury. The winter climate of Lafayette seems especially severe on conifers, probably due in part to the desiccating effect of the high winds. The drouth of June and July of this year was also very hard on conifers. During the extreme heat of July there was considerable sunscalding of the foliage of hard maples along city streets. *Rhytisma punctatum* was found on the leaves of hard maple in Orange County in October as was

also powdery mildew (*Phyllactinia corylea*) on chestnut foliage. H. F. Dietz reported chestnut blight due to *Endothia parasitica* in a nursery near Wabash and in a chestnut orchard in Spencer County. A leaf-spot of mulberry due to *Mycosphaerella morifolia* was noted in Fulton County. Powdery mildew (*Microsphaera alni*) occurred on a Russian oak (*Q. pedunculata*) on the Purdue campus. Anthracnose of sycamore caused by *Gnomonia veneta* was noted near Lafayette in May and specimens of twig, petiole, and leaf blade infection were sent in from Evansville the same month.

Ornamentals.—Aster wilt, due to *Fusarium conglutinans callistephi* (2) was very severe during June and July and many florists and owners of home gardens complained of this disease. Carnation rust (*Uromyces caryophilinus*) was as usual prevalent in greenhouses as was also snapdragon rust (*Puccinia antirrhini*). Jackson found crown-gall on cultivated yarrow (*Achillea ptarmica*) and reported (Mycologia 14: p. 119) a rust (*Puccinia emiliae*) on pot marigold (*Calendula officinalis*). Sweet peas in a greenhouse were very badly injured by a powdery mildew which in early May was causing the premature death of the plants. Downy mildew (*Pseudoperonospora cubensis*) was found on the leaves of a Cucurbita gourd in Fulton County. Roses were generally and severely injured by powdery mildew (*Sphaerotheca pannosa*) and complaints were received from eight counties. Burkholder reported a fair control of both powdery mildew and black spot (*Diplocarpon rosae*) under outdoor conditions by spraying with a 2-4-50 Bordeaux.

SUMMARY.

The diseases of outstanding importance as observed in 1921 were the Fusarium soil troubles, the mosaic diseases, apple scab and blotch, cantaloupe and cucumber bacterial wilt, peach bacterial spot, and tomato leaf-spot.

The diseases found in 1921 which have not, as far as could be ascertained, been previously recorded for Indiana are as follows: Ampelopsis (two species) leaf-spot—*Guignardia bidwellii;* apple fruit rot (*Phytophthora cactorum*) and brown bark spot; lima bean powdery mildew and Fusarium seed stain; sugar beet root rot; cantaloupe fruit rot (Fusarium); celery mosaic; chestnut powdery mildew (*Phyllactinia corylea*) and blight (*Endothia parasitica*); clover root rot (Fusarium), mosaic, and powdery mildew; cowpea bacterial spot, powdery mildew, and leaf-spot, *Cercospora cruenta;* eggplant fruit rot, *Phytophthora terrestris;* goldenseal blight, *Botrytis;* Cucurbita gourd downy mildew, *Pseudoperonospora cubensis;* lettuce, Botrytis crown rot and Rhizoctonia rosette; hard maple, *Rhytisma punctatum;* pot marigold rust, *Puccinia emiliae;* mulberry leaf-spot, *Mycosphaerella morifolia;* parsnip leaf-spot, *Cercosporella pastinacae;* pea, *Bacterium pisi;* peach, *Leptothyrium pomi* on twigs; pear sooty blotch; pepper fruit rot, *Phytophthora terrestris;* privet powdery mildew, *Microsphaera alni;* radish root invasion by *Peronospora parasitica;* spinach crown rot (Phytophthora), root-knot, and downy mildew (*Peronospora effusa*); squash Gloeosporium storage rot; tomato collar rot; turnip yellows, Alternaria leaf-spot, and powdery mildew; wheat, *Ophiobolus graminis.*

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INDIANA PLANT DISEASES, 1922.[1]

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This is the fourth of a series of annual summaries of the plant disease situation in the state (2)[3]. Attention is confined mostly to the dis-

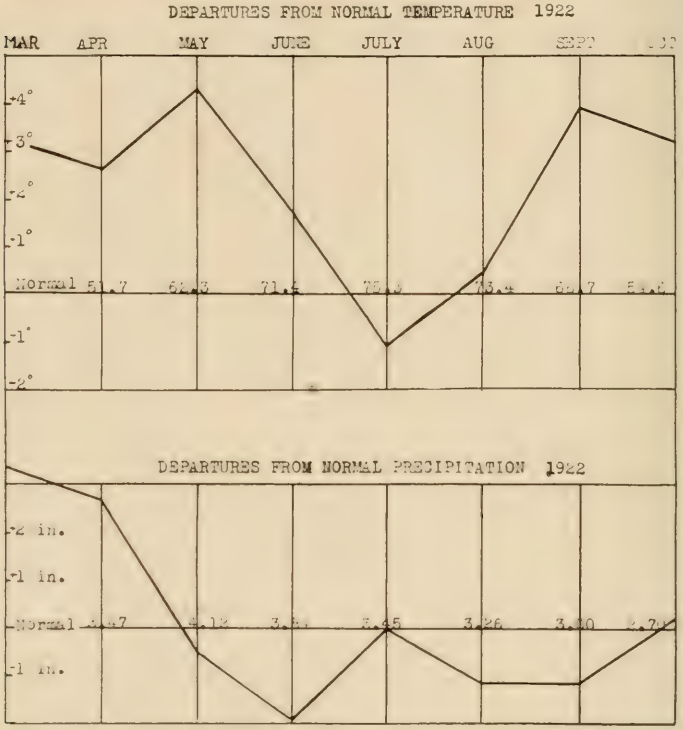

Fig. 1. Departures from normal temperature and precipitation based on monthly averages, 1922.

eases of economic importance on agricultural crops. No claim for completeness is made. The diseases are arranged alphabetically by hosts.

WEATHER CONDITIONS.

Temperature and rainfall have a very marked effect upon the prevalence of most diseases. The graphs in figure I represent the departures

[1] Contribution from the Botanical Department, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] The writer wishes to acknowledge the assistance and co-operation of H. S. Jackson, E. B. Mains, C. T. Gregory, G. N. Hoffer, J. B. Kendrick, C. L. Burkholder, F. P. Cullinan, H. D. Brown and F. C. Gaylord.

[3] Numbers in parenthesis refer to "literature cited".

from normal temperature and rainfall in Indiana in 1922 based upon monthly averages given by J. H. Armington, of the U. S. Weather Bureau, in the Indiana section of "Climatological Data." The season of 1922 was characterized by high temperatures during all the months except July and by high rainfall in the spring and low rainfall during May, June, August and September.

DISEASES ARRANGED BY HOSTS.

Alfalfa.—Leaf spot, caused by *Pseudopeziza medicaginis*, was of general occurrence. Mains reports rust (*Uromyces medicaginis*) exceptionally abundant.

Asparagus.—Rust (*Puccinia asparagi*) was worse than usual.

Aster.—Wilt due to *Fusarium conglutinans callistephi* was extremely severe owing to the hot dry weather.

Apple.—Blotch, caused by *Phyllosticta solitaria*, was very destructive on the susceptible varieties because of the warm wet spring and the failure of many growers to spray the year before. Infection started earlier than in 1920 and 1921 and the spray two weeks after petal fall was too late to prevent serious infection (3).

Scab, caused by *Venturia inaequalis*, was much worse than usual, probably because of the wet spring and the failure of many growers to spray in 1921. The heavy rains in April and a protracted blooming period not only favored scab but also rendered it difficult to apply the sprays on schedule time. Cullinan found scab severe on Grimes, a variety usually somewhat resistant to scab, and Burkholder reports that the disease caused early defoliation of an orchard of young Grimes trees. Cullinan found a serious reduction in the size of Ben Davis fruit due to early scab defoliation and found sulfur dust ineffective in controlling scab. The disease was severe on Fameuse, Winter Banana, Ben Davis, Red June, and Delicious. In an orchard of mixed varieties, Grimes, York, and Transparent showed resistance to leaf infection.

Black-rot, caused by *Physalospora cydoniae*, was widespread and serious. Late summer defoliation due to the leaf lesions was especially harmful and was not controlled by the sprays applied for scab and blotch. In an orchard of mixed varieties, York escaped leaf infection, and Grimes and Benoni showed much less leaf infection than Northwestern, Wealthy, Chenango, Transparent, Ben Davis, and Jonathan. Shallow bark infection was very conspicuous on old Ben Davis trees in an orchard in Miami County. The extreme heat of early September favored the fruit rot following scab, blotch, and insect injuries on early varieties.

Fire-blight, due to *Bacillus amylovorus*, was serious locally in Knox and Franklin counties, possibly due to the warm wet April and subsequent hot weather. Twig blight was prevalent in young orchards of Transparent, Oldenburg, Jonathan, and Willow. In certain cases, blighted pear trees were the evident source of infection for nearby apple trees. Blister canker, caused by *Nummularia discreta*, was favored by the hot dry summer weather. Powdery mildew occurred on young trees in Morgan County.

Rust (*Gymnosporangium juniperi-virginianae*) was much worse than usual due probably to the warm wet spring. Burkholder reported severe defoliation and complete loss of crop in the portion of a young orchard near a group of red cedars. Fruit infection was noted on Wealthy, Rome, Jonathan, Oldenburg, Salome, and Esopus. Leaf infection occurred on these varieties and on Red June, Benoni, Arkansas and Indiana Favorite. Twig infection was noted on 1922 wood of Jonathan and Rome. The rust cankers on Rome twigs as observed in Orange County, May 5, 1923, were red to brown, elliptical with a raised uniform margin often surrounded by a fissure in the bark. In many an elevated region at the center bore the remnants of pycnia and aecia. Some resembled the Bellflower twig lesions illustrated by Hopkins (9). In some cases the distal portion of the infected twig was killed and in some cases infection of spurs had progressed into the bark of older limbs causing considerable hypertrophy. Dried aeciospores were found in the old aecial cups.

Bitter rot, caused by *Glomerella cingulata*, caused one grower in Gibson County a great loss in Grimes, Stayman, Rome and Champion, owing apparently to heavy local rains accompanied by high temperatures late in July. The Grimes had not been sprayed, and the tendency to omit the fungicidal sprays on this variety is a dangerous practice in southern Indiana where bitter rot may occur. Brown rot, caused by *Sclerotinia cinerea*, occurred on unsprayed Esopus fruit in transit from Orange County and in a car of Transparents from Madison County.

The surface type of bitter pit was a severe blemish on many varieties, according to Cullinan. It was found on Grimes, Mann, Ben Davis, Stayman, and Arkansas. A reduction in size of fruit and early maturity and dropping were attributed to the hot dry weather of August and September, in the case of Jonathan, Grimes, Winesap, and Ben Davis. Water core was found on Northwestern. Frost marks were conspicuous on Ben Davis fruit in Miami County.

Sooty blotch and fly speck (*Gloeodes pomigena* and *Leptothyrium pomi*) were not serious, probably because of the dry August and September. The blemishes were noted on Wealthy, Grimes, Maiden Blush, Jonathan, and York. What appears to be the same fungi were noted on the stems of *Smilax hispida*.

Barley.—The following diseases of barley occurred: Stripe, caused by *Helminthosporium gramineum;* loose smut (*Ustilago nuda*); covered smut (*Ustilago hordei*); stem rust (*Puccinia graminis*); and leaf rust (*Puccinia simplex*).

Bean.—Blight, caused by *Bacterium phaseoli*, seemed to be less destructive than usual, possibly owing to the general drouth.

Mosaic was the most destructive disease of this crop. In a plot of 52 varieties grown by H. D. Brown, 35 showed mosaic. Wardwell's Kidney Wax and Black Valentine, which showed no mosaic in a similar plot in 1921, also showed none this year, while the other four varieties which remained free in 1921 showed mosaic as follows: Red Kidney, 2%; Saddleback Wax, 8%; Dwarf Horticultural, 49%; Robust Pea, 1%.

A serious outbreak of rust (*Uromyces appendiculatus*) occurred in

the fall on Kentucky Wonder pole beans in market gardens where overhead irrigation was practiced. The foliage was destroyed and plants were killed outright. Abundant and conspicuous pod lesions occurred.

Lima Bean.—Blight due to *Bacterium phascoli* was rather serious. A Sclerotinia stem rot was noted.

Beet.—Leaf-spot, due to *Cercospora beticola*, was serious in garden and sugar beets. The peculiar mosaic-like disease noted in 1921 was severe in sugar beets.

Blackberry.—Rust (*Kunkelia nitens*) occurred on wild and cultivated plants in southern Indiana.

Cabbage.—Yellows, caused by *Fusarium conglutinans*, was especially destructive because of the hot dry weather. The disease was reported from 31 counties. The use of resistant types is becoming general. In the spring black-leg, caused by *Phoma lingam*, was found serious locally by Gregory, who also noted black rot, due to *Pseudomonas campestris*, in a few localities. A Sclerotinia stem-rot was noted in Lake County.

Cantaloupe.—Bacterial wilt caused by *Bacillus tracheiphilus* was as usual the most serious disease. Anthracnose (*Colletotrichum lagenarium*) fruit lesions were found on the Tip-top variety in October. Leaf blight caused by *Alternaria brassicae nigrescens* was very serious, causing premature death of the leaves and poor flavor in the fruit. Mosaic was worse than usual, stunting the plants and preventing proper maturity of the fruit. Milkweed, a mosaic carrier, was found commonly in diseased fields.

Carrot.—Leaf-spot, caused by *Cercospora apii carotae*, was noted in market gardens.

Cauliflower.—Stem rot, due to *Sclerotinia libertiana*, was noted in May, killing scattered plants.

Celery.—The high temperature of this summer favored the Fusarium yellows disease which is fatal to the Golden Self-blanching variety and is widespread in market gardens. Early blight caused by *Cercospora apii* remained the most prevalent celery disease. A few cases of mosaic were noted.

Cherry.—The limiting factor in cherry growing is the leaf-spot, due to *Coccomyces hiemalis*, which causes serious defoliation and devitalization of the trees. Burkholder reports it worse than usual this year and complaints were received from growers in eleven counties during June and July. Brown rot (*Sclerotinia cinerea*) was worse than usual owing to the warm weather. Powdery mildew was noted.

Clover.—In common with the rest of the country, all Indiana clover fields became conspicuously whitened with an unprecedented epidemic of powdery mildew (*Erysiphe polygoni*). The attack lasted all season and occasioned innumerable inquiries, mostly concerning the possible injuriousness of the mildewed clover as feed for live-stock. Mains (12) found that the mildew was restricted to red clover and that American varieties were more susceptible than European varieties. Mosaic occurred very generally on red clover. Mains noted rust (*Uromyces trifolii*) rather sparingly.

Corn.—Hoffer found that root and stalk rots, caused by Gibberella and Fusarium species, were less prevalent than usual, as were also the ear rots due to Fusarium and Diplodia. Hoffer and Trost (8) have found that excess iron and aluminium compounds in the soil predispose the corn plant to infection, particularly at the nodes.

Smut (*Ustilago zeae*) was less prevalent than usual.

Rust (*Puccinia sorghi*) occurred to a slight extent. One case of brown spot due to *Physoderma zeae-maydis* was found by J. F. Trost. Bacterial wilt caused by *Aplanobacter stewartii* was found abundantly on sweet corn in home gardens, and was favored presumably by the hot weather.

Cowpea.—The bacterial spot disease (5), caused by *Bacterium vignae*, was widespread, probably because it is seed-borne. Powdery mildew was very destructive on cowpeas grown in a greenhouse. A few mosaic plants were found in Knox County.

Cucumber.—Wilt caused by *Bacillus tracheiphilus* and mosaic are the worst diseases of both garden cucumbers and the pickle crop. Mosaic has become so prevalent in its weed hosts that cucumber growing is unprofitable in many localities. As a result of seed disinfection, angular leaf spot, due to *Bacterium lachrymans*, is no longer destructive in the pickle crop. Anthracnose occurred in certain greenhouses.

Currant.—Root rot, caused by *Fomes ribis*, was found in Jefferson County by Cullinan.

Eggplant.— Leaf spot, caused by *Phomopsis vexans*, and a serious wilt disease were of common occurrence.

Gooseberry.—Anthracnose, caused by *Pseudopeziza ribis*, was destructive locally.

Grape.—Black rot, caused by *Guignardia bidwellii*, was found on the green fruit in a sprayed vineyard in Brown County on July 26. Dead-arm, caused by *Cryptosporella viticola*, was destructive early in the season and was reported from four localities.

Kale.—Yellows, due to *Fusarium conglutinans*, was noted in Marion County in May.

Lettuce.—Downy mildew (*Bremia lactucae*) was destructive in greenhouses, as was also drop due to *Sclerotinia libertiana*. Leaf-spot, caused by *Septoria consimilis*, was found serious in market gardens in October. A stunting due to an excess of soluble salts in the soil occurs commonly in greenhouses.

Mustard.—Mosaic was noted in market gardens in October.

Oats.—The smuts (*Ustilago avenae* and *U. levis*) caused the usual loss. Crown rust was serious and stem rust was noted.

Onion.—Smut (*Urocystis cepulae*) occurred in Lake and Jasper counties (7). Smudge (*Colletotrichum circinans*) was noted in market gardens. The U. S. Bureau of Markets reported black mold (*Aspergillus niger*), blue mold (*Penicillium sp.*), neck rot (*Botrytis sp.*), Fusarium rot, and bacterial soft rot in car-lot shipments from Indiana.

New Zealand Spinach.—A leaf spot caused by a species of Cercospora was found in October.

Parsnip.—Leaf-spot, caused by *Cercosporella pastinacae*, was found in October.

Pea.—A root-rot was found by Gregory in Vigo County in May, causing a heavy loss. The roots were blackened and black cankers occurred at the bases of the stems.

Peach.—Bacterial spot, caused by *Bacterium pruni*, remains the worst disease of this crop, owing to the premature defoliation, twig blight, and fruit infection. The high temperatures of this year favored the disease. Exposure of the fruit by this defoliation resulted in severe sunscald in July. Defoliation had begun as early as April 27 in Knox County. A trace of the disease was found in a peach nursery.

The dormant spray controls leaf curl, due to *Exoascus deformans*, very effectively and serious outbreaks occur only in orchards not well sprayed. Peculiar, red, protuberant fruit lesions were noted. Scab, caused by *Cladosporium carpophilum*, occurred rather generally in southern Indiana. Brown rot, caused by *Sclerotinia cinerea*, was serious in unsprayed orchards and on fruit affected with sunscald and caused some losses in transit to market. Cankers on small limbs with which *Valsa leucostoma* was associated were found in February by Burkholder.

Throughout southern Indiana the fruit suffered severely from sunscald in July, especially on trees defoliated by *Bacterium pruni*, and widespread alarm was occasioned among growers. Large, red-bordered brown necrotic areas appeared on the upper exposed surfaces usually near the stem. These occurred on unsprayed as well as sprayed trees and hence were not attributable to spray injury.

Pear.—Fire-blight, due to *Bacillus amylovorus*, was worse than in 1921, owing probably to the warm wet spring, and was reported from ten counties. Scab, due to *Venturia pyrina*, occurred on leaves and fruit in northern Indiana. Black rot caused by *Physalospora cydoniae* was destructive. The conspicuous fruit lesions of *Fabraea maculata* were noted in Knox County.

Pepper.—Mosaic was of general occurrence in market gardens. Leaf infection of bacterial spot, caused by *Bacterium vesicatorium* (6), was found in market gardens.

Plum.—Black knot, caused by *Plowrightia morbosa*, occasioned a number of inquiries. Brown rot, caused by *Sclerotinia cinerea*, was serious on unsprayed trees. Gregory noted crown gall (*Bacterium tumefaciens*) and Burkholder noted plum pockets due to *Exoascus pruni*. Gregory found the latter on wild plums also. Fruit lesions of *Bacterium pruni* were found on Abundance plums in Jefferson County.

Potato.—The hot dry weather was very favorable to Fusarium wilt which was prevalent in the early crop in southern Indiana and the late crop in northern Indiana. Leaf-roll has proved to be the most serious disease of the late crop Rurals, causing a marked decrease in yield even though its symptoms cannot be recognized readily in the field. Because of the spread of this disease under Indiana conditions it is advisable to use certified northern-grown seed stocks. Mosaic is the most serious disease of the early crop (Early Ohios and Irish Cobblers) and occurs occasionally in Rurals. It reduces the yield even more severely than

leaf-roll and supplies another potent reason for using northern-grown certified seed stocks. Mosaic may be more readily detected in the field than leaf-roll.

Black-leg, caused by *Bacillus phytophthorus*, was noted in the early crop. Early blight, caused by *Alternaria solani*, occurred rather generally late in the season. Tuber blemishes due to scab (*Actinomyces scabies*) and black scurf (*Rhizoctonia solani*) were generally prevalent where seed disinfection was omitted or soil infestation existed. The hot weather made scab worse. Silver scurf, caused by *Spondylocladium atrovirens*, was found causing a shrivelling of potatoes of the 1921 crop in storage.

Quince.—Fruit lesions of *Fabraea maculata* were found in Miami County as well as an Alternaria rot of the fruit.

Radish.—Black-root, caused by *Nematosporangium* (*Rhcosporangium*) *aphanidermatum*, occurred very generally near Lafayette early in the spring.

Raspberry.—Anthracnose, caused by *Plectodiscella veneta*, is the limiting factor in the black cap industry and by its girdling effect near the ground line kills the canes just before the fruit is matured. Leaf spot, caused by *Mycosphaerella rubi*, occurred very generally. Crown gall was noted in a few localities.

Rhubarb.—Leaf-spot, caused by *Ascochyta rhei*, was prevalent as usual.

Rye.—Anthracnose, caused by *Colletotrichum cereale*, stem rust, stem smut (*Urocystis occulta*), powdery mildew (*Erysiphe graminis*), and ergot (*Claviceps purpurea*) were reported.

Soybean.—Blight caused by *Bacterium glycineum* was widespread. Mosaic occurred in variety test plots and greatly lowered the yield of seed (11).

Spinach.—Brown reported mosaic severe in the market garden winter crop near Evansville.

Strawberry.—Leaf-spot, caused by *Mycosphaerella fragariae*, was very serious. It was also noted on cinquefoil. A Sclerotinia stem rot was found in June.

Sweet Potato.—Fusarium wilt and black rot (*Ceratostomella fimbriata*) were noted.

Tomato.—Leaf-spot, caused by *Septoria lycopersici*, was serious in the canning crop in central and especially southern Indiana and in gardens. The worst defoliation was noted on the poorer soils in Gibson County. The summer drouth tended to check the disease.

The hot dry summer was favorable to wilt, caused by *Fusarium lycopersici*, which was the most destructive disease of this crop this year. In the canning crop the disease was associated with the use of southern-grown plants. Evidence was obtained that the fungus persists four years in the soil. Mosaic was generally prevalent in fields and greenhouses and was more or less associated with the weed carriers (4). Fruit lesions were not uncommon. In field tests at Kempton the effectiveness of eradication of the weed hosts, Physalis species, was shown.

Early blight, caused by *Alternaria solani*, caused a collar-rot in the field in Hancock County as a result of plant-bed stem lesions, and also a prevalent spotting of the late-set fruits. These fruit spots were oval or circular, with an even margin, sunken, smooth, black or brown in color and in no way resembled the nailhead spot of the south. Leaf mold, caused by *Cladosporium fulvum*, was very destructive in greenhouses and was noted sparingly in the field. Buckeye rot, caused by *Phytophthora terrestris*, was serious on the low-hanging fruits in certain greenhouses. It did not occur in the field where it was serious in 1921 (10), however.

Seed disinfection combined with unfavorable dry weather rendered basterial spot, caused by *Bacterium vesicatorium*, very uncommon (6). Bacterial wilt, caused by *Bacillus solanacearum*, was found in a greenhouse in Cass County in May causing the death of the plants. The pith and vascular elements were brown and watersoaked and the lower leaf petioles were reflexed as Dr. E. F. Smith has pointed out (13, p. 179). There were brown or black surface lesions along the upper side of the petioles. The causal organism was isolated and its pathogenicity proved. Bluish pigment formation was shown by colonies on potato dextrose agar.

Anthracnose of the ripe fruit due to *Gloeosporium phomoides* was very abundant in the canning crop in October. Nematode root-knot was serious in greenhouses and was found in a few fields. Blossom-end rot was not particularly severe. Hollow stem in the young plants was more common than usual. Lightning injury (1) was found in one field.

Watermelon.—Anthracnose (*Colletotrichum lagenarium*) was less prevalent than usual, due to the dry weather, while the heat favored the wilt, due to *Fusarium niveum*. The leaf-spot, due to *Alternaria brassicae nigrescens*, was noted. Blossom-end rot occurred rather commonly.

Wheat.—Loose smut (*Ustilago tritici*) was very serious where untreated seed was used. Covered smut (*Tilletia laevis*) was of minor importance. Stem rust (*Puccinia graminis*) was severe only near barberries, according to K. E. Beeson, who reports four serious and two minor outbreaks in the state this year. These were in Rush, Decatur and Johnson counties. Mains reports leaf rust (*Puccinia triticina*) the most serious wheat disease of the season, causing a reduction in yield of about 7 per cent. It was worst in the southern third of the state.

Scab, caused by *Gibberella saubinetii*, occurred only rarely. Anthracnose (*Colletotrichum cereale*) was not serious. Septoria leaf-spot was found near Laporte by Kendrick, causing a yellowing and stunting of the young plants. Powdery mildew (*Erysiphe graminis*) occurred to a slight extent. Rosette was found in Laporte County by Kendrick. Jackson found a small amount of foot-rot on the farm in Knox County where he found *Ophiobolus graminis* in 1921.

Forest and shade trees.—Among trees, the following diseases should be recorded: Powdery mildew of catalpa from Floyd County; chestnut blight, due to *Endothia parasitica*, in a nursery at Lafayette; cedar rust on flowering crab; Penicillium and Fusarium rots of hickory nuts;

maple anthracnose (*Gloeosporium apocryptum*) extremely serious and widespread, occasioning numerous inquiries from seven counties; maple tar-spot (*Rhytisma acerinum*) in Whitley County; maple sunscald and drouth injury of leaves very prevalent owing to the hot dry weather; and sycamore anthracnose (*Gloeosporium nervisequum*) causing defoliation in May.

Ornamentals.—Among ornamentals the following diseases occurred: a bacterial soft rot of calla lilies in a greenhouse; carnation rust (*Uromyces caryophilinus*) in greenhouses; the bacterial spot of geraniums, due to *Bacterium erodii*, in greenhouses at Lafayette; the hard rot of gladiolus, due to *Septoria gladioli*; hollyhock rust (*Puccinia malvacearum*); the Botrytis blight of peonies; rose powdery mildew (*Sphaerotheca pannosa*), which was very destructive and occasioned inquiries from eight counties; rose black spot, due to *Diplocarpon rosae*; snapdragon rust (*Puccinia antirrhini*), which was very serious; and sunflower downy mildew (*Plasmopara halstedii*).

SUMMARY.

The diseases of outstanding economic importance were the Fusarium soil troubles, the mosaic diseases, apple scab, blotch, and rust, cherry leaf spot, clover powdery mildew, peach bacterial spot and sunscald, potato leaf roll, raspberry anthracnose, and the cereal leaf rusts. Clover powdery mildew attracted the most attention.

The diseases found in 1922 which have not been previously recorded for Indiana in the Academy Proceedings are as follows: Lima bean stem rot—*Sclerotinia libertiana*; calla lily bacterial soft rot; cauliflower stem rot—*Sclerotinia libertiana*; cowpea mosaic; currant root rot—*Fomes ribis*; geranium bacterial spot—*Bacterium erodii*; gladiolus hard rot—*Septoria gladioli*; meadow fox tail leaf spot—*Scolecotrichum graminis*; mustard mosaic; New Zealand spinach leaf spot—*Cercospora* sp.; peach sunscald; peony blight—*Botrytis* sp.; pepper bacterial spot—*Bacterium vesicatorium*; plum crown gall; strawberry stem rot—*Sclerotinia* sp.

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DOES ALLIUM VINEALE L. PRODUCE SEEDS IN INDIANA.[1]

ALBERT A. HANSEN, Purdue University.

Whether or not wild garlic, *Allium vineale* L., produces seeds under Indiana conditions is a mooted question the answer to which is of economic importance inasmuch as wild garlic is the most damaging of weeds in southern Indiana and data regarding methods of propagation are of the utmost importance. The damage attributable to wild garlic may be measured by the fact that a survey conducted in Vanderburgh, Perry, Warrick, Dubois, Spencer, Gibson, Pike and Posey counties during 1922 by the Purdue University Agricultural Extension Department, revealed that during 1921 a total of 1,132,166 bushels of garlicky wheat and 40,130 gallons of garlicky cream were marketed from the area covered by these eight counties in which a total of 463,594 acres of cultivated land is infested with this serious weed.

Fig. 1. Heads of *Allium vincale* showing flowers arising from between the aerial bulblets. It was from these flowers that seeds were secured.

The ordinary method by which wild garlic reproduces is by means of aerial and subterranean bulblets. In common with many species that possess vigorous means of vegetative reproduction, seeds are rarely formed, although no record can be found containing definite data on the subject. Perhaps the most exhaustive treatise on the biology of *Allium vineale* in Indiana is the work of Pipal who states[2] "propagation of wild garlic by seed takes place mostly in the southern limits of its range.

[1] Contribution from the Botany Department (Extension Division), Purdue University Agricultural Experiment Station.

[2] Pipal, F. J. "Wild Garlic and Its Eradication." Bul. 176, Purdue University Agricultural Experiment Station, 1914, p. 11.

No plant has been found, so far as known to the writer, producing seed in Indiana." On the other hand, Watts states that under Tennessee conditions each garlic head usually contains about six flowers each of which produces from three to six seeds, and nearly 100 per cent of the seeds are viable and produce mature plants the season following their formation.[3]

On November 20, 1922, the writer found a number of wild garlic plants in Dubois County, Indiana, that were conspicuous on account of the clusters of flowers formed on each head (fig. 1). An examination of the flowers revealed the presence of seeds, most of which were somewhat shriveled although a number of them were plump and appeared to be viable. A dozen of these heads were collected from which slightly over two hundred seeds were secured.

The seeds were separated into two lots of one hundred each. One lot was tested for germination by the writer, using moistened blotters at ordinary room temperature for the purpose, while the other lot was sent to the Seed Laboratory of the Purdue University Agricultural Experiment Station. Germination tests were conducted for periods of thirty and thirteen days and in neither case did a single seed germinate.

These data suggest that the production of seeds by *Allium vineale* L. under Indiana conditions is very unusual while the formation of viable seeds either does not occur or is rare.

RECENT INDIANA WEEDS, 1923.[1]

ALBERT A. HANSEN, Purdue University.

This paper attempts to record the occurrence in Indiana of plants known to have pronounced weedy characteristics and which are new in the state or else have recently developed troublesome tendencies. The present paper is a continuation of the record started in the "Proceedings of the Thirty-eighth Meeting (1922) of the Indiana Academy of Science". It covers the period from October 1, 1922, to October 1, 1923.

For assistance in verifying identifications thanks are due Dr. B. L. Robinson, of the Gray Herbarium, Dr. John K. Small, of the New York Botanical Garden and Dr. S. F. Blake of the United States Department of Agriculture. Specimens of the plants listed have been deposited in the herbarium of the Purdue University Agricultural Experiment Station.

Fanweed.—*Thlaspi arvense* L. This is one of the most feared of grainfield weeds in Minnesota, North and South Dakota, Colorado and throughout the grain-growing sections of western United States and Canada. Fanweed is a European annual that is noted for its prolific seed production and is the subject of several western experiment station bulletins.

[3] Watts, R. L. "The Wild Onion." Tenn. Agr. Exp. Sta. Bul., Vol. VII, No. 2, 1895, p. 31.

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

Fanweed (Frenchweed, penny cress, stinkweed) was located during early June in an alfalfa field on the John Danglade Farm in Switzerland County. The infested section of the field was immediately cut and burned and it is hoped that the weed was completely destroyed by this means. The same species was again located during early September on the farm of E. D. Stevenson, Carlos, Indiana, where it was going to seed in a cornfield.

Knawel or German Knot Grass.—*Scleranthus annuus* L. Knawel is one of the worst of weeds in the trucking districts of Virginia and in other sections of the eastern United States, but the plant is rare in the middle west. The species is not represented in the Gray Herbarium by specimens from Indiana and has previously been reported but once in this state, when it was recorded by Nieuwland at Webster's Station.[2] Knawel was collected at Shipshewana, Indiana, on July 19, 1923, where it is a weed of scattered occurrence.

Gumweed.—*Grindelia squarrosa* Dunal. Gumweed is a dangerous weed in the wheat fields of the northwest where the gummy parts of the flowering heads remain in the wheat after threshing and impart a disagreeable pine-like odor and flavor to the flour. It is a perennial that is native on the western plains.

The only record of the occurrence of gumweed in Indiana is a single report from Cass County recorded in Coulter's catalogue of Indiana plants. Specimens were received on July 20, 1923, from West Lebanon, Indiana, and one of them was deposited in the Gray Herbarium, which previously contained no record of the occurrence of this species in Indiana.

Yellow Star Thistle.—*Centaurea solstitialis* L. The yellow star thistle is reputed to be one of the most damaging of grainfield weeds in California. The species was located on the farm of Cyrus McGregor, Princeton, Indiana, R. R. 1, where it infested a field of alfalfa. The seeds of the yellow star thistle are difficult to remove from alfalfa and the plant was probably introduced by means of impure seed.

Hoary Alyssum.—*Berteroa incana* DC. Hoary alyssum is said to have been introduced into the United States comparatively recently by means of European red clover seed. On account of its prolific seed production this species is thought to be a dangerous weed the further spread of which should be stopped. The plant is becoming common in New England and New York where it was first noted about thirty years ago.

Specimens of hoary alyssum were received on June 16, 1923, from County Agent C. A. Jackson, of Goshen, with the notation that the plant is a weed on a run-down eighty acre farm in Elkhart County. A small patch of the plant was found by the writer thriving on a vacant lot in West Lafayette, but all members of this small colony were destroyed before seeds ripened.

Hare's Ear Mustard.—*Conringia orientalis* Dumort. This species is of comparatively recent occurrence in the United States. It is said to have been introduced during the early nineties in European flax seed.

[2] Amer. Mid. Nat., 3:280:1914.

Since then it has developed into a noxious grainfield weed throughout the grain-producing areas of the northwest.

A number of specimens of this plant were received on June 8, 1923, from L. M. Busche, of Decatur, Adams County, Indiana, where the species is apparently established as a grainfield weed.

Miscellaneous.—Among new species found in Indiana that are not known to be noxious in other parts of the United States may be mentioned yellow alfalfa, *Medicago hybrida* (Pourr.) Traut., common along fence rows on the Purdue Farm in West Lafayette, and *Navarretia pubescens*, Hook. and Arn., a number of flowering specimens of which were found in a clover field in Randolph County on August 29, 1923. *Radicula palustris* (L) Moench, of common occurrence on moist land throughout Indiana but not ordinarily considered as a noxious weed, was found to be exceedingly troublesome near Veedersburg.

The Division of Botany of the Purdue University Agricultural Experiment Station will appreciate data regarding the occurrence of new plants in Indiana that are apt to prove troublesome as weeds. Information of this character is particularly valuable when the infested area is small, since an attempt is being made to eradicate potentially troublesome plants before they have had an opportunity to become widespread.

A WEED SURVEY OF INDIANA.[1]

ALBERT A. HANSEN, Purdue University.

A regional flora, such as Coulter's "Flora of Indiana", records the occurrence of plants but gives little information regarding the degree to which weedy species are troublesome.

In order to secure data of this type a weed survey of Indiana is being undertaken by the Extension Division of the Botanical Department of the Purdue University Agricultural Experiment Station. Three sources of information are being used, (1) the county agent, (2) field observations and (3) the experience of individual farmers, secured from correspondence and by the questionnaire method.

The first step in securing this information was taken during the winter of 1922 when a questionnaire was sent to the county agents in 84 counties of the state. Each agent was asked to give the names of the five worst weeds in his county, and 71 replies were secured. Since the county agent, by the very nature of his occupation, is usually best qualified to give information concerning agricultural matters in his county, it is felt that reliable information was secured by this method. The results are not only of general interest, but have a practical value. They may also be of ecologic interest in present and future studies of the weed problem in Indiana.

The reports from the different counties are shown graphically in figure 1. The county numbers on the map each represent a species

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

and the numbers are arranged in the order of importance in which the species were reported by the county agents. The key to these numbers will be found in the following list which was compiled from the county

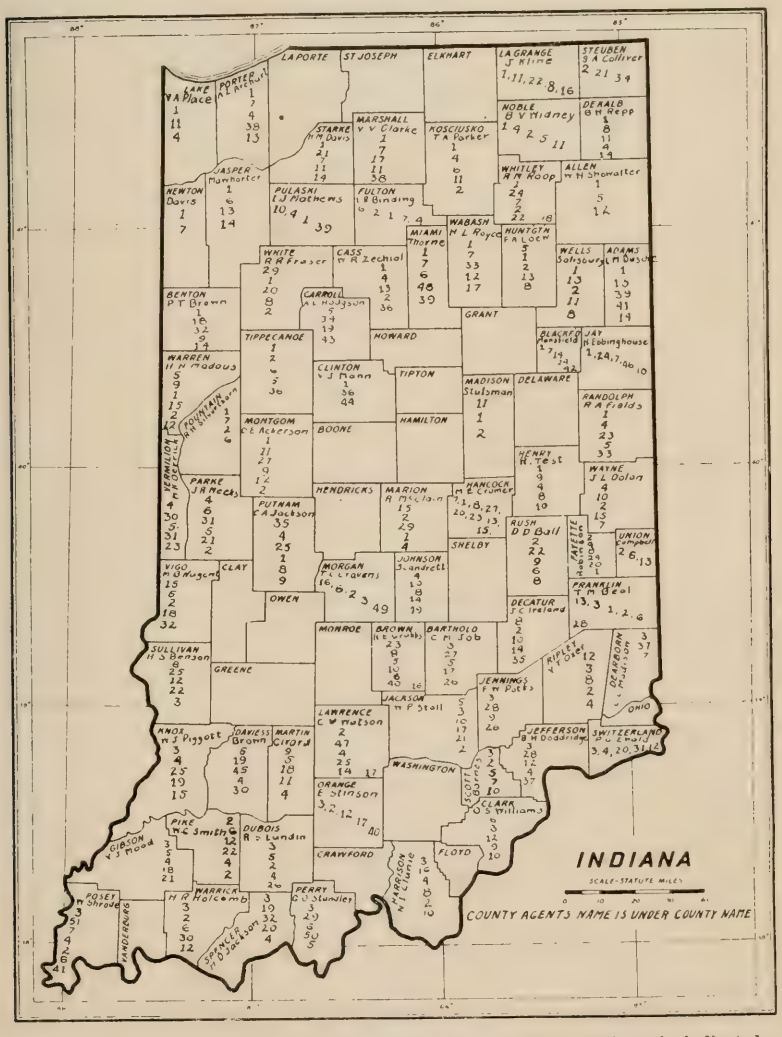

Fig. 1. The distribution of the most troublesome weeds in Indiana is indicated on this map. The key will be found on page 218. Canada thistle (1) is most common in northern Indiana, wild garlic (3) is the most abundant in southern Indiana, while white top (2), buckhorn (4), wild morning glory (5) and red sorrel (6) are leading weeds in all parts of the state.

agent reports. The names of the county agents who coöperated in this survey are indicated on the map. No reports were received from the counties in blank.

	Name	No. times reported	No. times reported as first in importance
1.	Canada thistle (*Cirsium arvense*)	38	26
2.	White top (*Erigeron annuus* and *ramosus*)	32	4
3.	Wild garlic (*Allium vineale*)	21	16
4.	Buckhorn (*Plantago lanceolata*)	29	3
5.	Wild morning glory (*Convolvulus sepium*)	18	5
6.	Red sorrel (*Rumex acetosella*)	17	3
7.	Horse or Bull nettle (*Solanum carolinense*)	15	1
8.	Wild carrot (*Daucus carota*)	15	1
9.	Cocklebur (*Xanthium canadense* and *commune*)	11	1
10.	Ragweed (*Ambrosia artemisiifolia*)	11	1
11.	Quack grass (*Agropyron repens*)	11	0
12.	Dodder (*Cuscuta epithymum* and *arvensis*)	11	0
13.	Wild mustard (*Brassica* spp. and *Barbarea vulgaris*)	9	1
14.	Foxtail (*Setaria glauca* and *viridis*)	9	0
15.	Wild Lettuce (*Lactuca scariola*)	6	2
16.	Ox-eye daisy (*Chrysanthemum leucanthemum*)	5	2
17.	Cockle (*Agrostemma githago*)	5	0
18.	Smartweed (*Polygonum* spp.)	5	0
19.	Crab grass (*Digitaria sanguinalis*)	5	0
20.	Bindweed (*Convolvulus arvensis*)	5	0
21.	Sandbur (*Cenchrus pauciflorus*)	5	0
22.	Narrow leaf dock (*Rumex acetosella*)	5	0
23.	Wild Sweet Potato (*Ipomoea pandurata*)	4	1
24.	Flower-of-an-hour (*Hibiscus trionum*)	4	0
25.	Bracted plantain (*Plantago aristata*)	4	0
26.	Cheat (*Bromus secalinus*)	3	0
27.	Trumpet creeper (*Tecoma radicans*)	3	0
28.	Wild onion (*Allium canadense*)	3	0
29.	Wild parsnip (*Pastinaca sativa*)	3	0
30.	Common plantain (*Plantago rugelii*)	3	0
31.	Peavine (*Vicia* spp.)	3	0
32.	Johnson grass (*Holcus halepensis*)	3	0
33.	Butter-print weed (*Abutilon theophrasti*)	3	0
34.	Pigweed (*Amaranthus retroflexus*)	3	0
35.	Ironweed (*Vernonia fasciculata* and *novebora-censis*)	2	1

The following species were each reported twice, although in no case as first in importance: 36, white snakeroot (*Eupatorium urticaefolium*); 37, wild cucumber (*Echinocystis lobata*); 38, Russian thistle (*Salsola kali*, var. *tenuifolia*); 39, burdock (*Arctium minus*); 40, broom sedge (*Andropogon virginicus*); 41, chickweed (*Stellaria media*).

The following were each reported once and in no case as first in importance: 42, chicory (*Cichorium intybus*); 43, horseweed (*Erigeron canadensis*); 44, water hemlock (*Cicuta maculata*); 45, jimson weed (*Datura stramonium*); 46, fall aster (*Aster ericoides*); 47, cedar weed

(?); 48, wild artichoke (*Helianthus tuberosus*); 49, wild pepper (?); 50, sour beet (?); 51, wild corn (*Andropogon sorghum drummondii*).

The specific identity of the weeds listed is doubtful in some cases. The common name wild mustard probably includes not only the true wild mustards in the genus *Brassica* but also *Barbarea vulgaris*, which has become exceedingly abundant in Indiana during recent years. In some cases in which two common names are given for what is obviously the same plant (such as narrow-leaf plantain and buckhorn, woodbine and trumpet creeper) only one common name is used in the above compilation. The technical names were supplied by the writer.

The results of the survey indicate that Canada thistle is the worst weed in northern Indiana, wild garlic is the worst weed in southern Indiana and white top, buckhorn, wild morning glory and red sorrel are the leading weeds that are prevalent in all parts of the state.

PLANTS NEW OR RARE IN INDIANA—XII.

CHAS. C. DEAM, Bluffton, Ind.

Specimens of all of the plants reported in this paper are in the writer's herbarium. The grasses were determined by Agnes Chase; the Carex by K. K. Mackenzie; the Penstemon by F. W. Pennell; and the determinations of the remainder were checked at the Gray Herbarium.

Melica purpurascens (Torr.) Hitchc. Cass County, May 21, 1923. No. 38,375. Among the limestone outcrops on top of the wooded bluff of the second bottom of the north side of the Wabash River about six miles southwest of Logansport.

Asperella Hystrix (L.) Humb. var. *Bigeloviana* Fernald. Huntington County, Aug. 17, 1923. No. 39,561. In a sugar maple woods on the south side of the Wabash River five miles southeast of Huntington. Jennings County, June 23, 1912. No. 11,252. Slope of a wooded ravine between Vernon and North Vernon. Porter County, July 10, 1920. No. 31,493. In the Doran woods about four miles southwest of Michigan City.

Eleocharis Wolfi Gray. Jefferson County, June 19, 1923. No. 38,893. In a low clearing three and a half miles southwest of Hanover.

Scirpus pauciflorus Lightfoot. Lagrange County, June 22, 1922. No. 36,640A. Low marl border of the east side of Fish Lake about five miles southeast of Lagrange. Reported by Higley and Raddin for Lake County in wet soil south of Whiting.

Carex brachyglossa Mackenzie. Knox County, June 5, 1923. No. 38,705. In a flat white and pin oak woods about seven miles northwest of Decker.

Trillium cernuum var. *macranthum* Eames and Wiegand. Laporte County, May 24, 1923. No. 38,496. In a low woods eight miles east of Michigan City, associated with white elm and silver maple. Petals oval, white; anthers purplish; base of stigma crimson.

Geum virginianum var. *Murrayanum* Fernald. From DeKalb, Elkhart, Hamilton, Hendricks (Mrs. Chas. C. Deam), Howard, Randolph, Rush and Tipton (Mrs. Chas. C. Deam) counties.

Callitriche autumnalis L. Reported from Lake County in Proc. Ind. Acad. Science 1920:227:1921; is now referred to *Callitriche heterophylla* Pursh.

Hypericum adpressum Bart. Jasper County, Sept. 16, 1923. No. 39,873. In a roadside ditch four miles east of Roselawn.

Jussiaea decurrens (Walt.) DC. Posey County, Sept. 28, 1923. No. 39,922. Growing in sandy soil on the wet border of a small body of water formed by a spring on the east side of the road on the northeast side of the cypress pond which is about thirteen miles southwest of Mt. Vernon. Spencer County, Oct. 3, 1923. No. 39,957. On the muddy border of a small stream in the Wilkerson woods in the northeast corner of Sec. 3 about one mile north of Enterprise. The plants ranged in height from 40 to 81 inches.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

Osmorhiza longistylis var. *villicaulis* Fernald. From Gibson, Johnson, Knox, Laporte, Marion, Noble, Posey, Warren and Wayne counties. The variety is almost as frequent as the smooth form.

Myosotis macrosperma Engelm. Daviess County, June 4, 1923. No. 38,651. In a low woods on the John Kehoe farm about one and a half miles northeast of Glendale.

Nepeta hederacea var. *parviflora* (Benth.) Druce. Fernald calls attention in Rhodora Vol. 23:289:1921 to two forms of the ground ivy. The small-flowered form (var. parviflora) is our common form and I have it from Bartholomew, Blackford, Carroll, Decatur, Elkhart, Floyd, Fountain, Hendricks, Huntington, Knox, Marion, Miami, Monroe, Morgan, Tippecanoe, Wabash and Wells counties. The large-flowered form (the type of the species) is rare in Indiana. I have it only from Clark, Hamilton and Randolph counties.

Penstemon spp. The forms of this genus reported for Indiana under the names of *Penstemon laevigatus*, *P. pubescens* var. *laevigatus*, *P. Penstemon;* and *Penstemon Digitalis* and *P. laevigatus* var. *Digitalis* are represented by five instead of two species. Since the forms reported represent a complex, it will be necessary in the total absence of verifying specimens to disregard the old reports and start anew. I will report the stations I have of the four species and the fifth will be described later by Mr. F. W. Pennell.

Penstemon calycosus Small. I have this species from Crawford, Daviess, Dearborn, Decatur, Dubois, Fayette, Greene, Hancock, Hendricks, Jackson, Jennings, Johnson, Lawrence, Martin, Morgan, Owen, Perry, Putnam, Randolph, Rush, Shelby, Spencer and Washington counties.

Penstemon digitalis (Sweet) Nutt. I have this species from Blackford, Clark, Franklin, Gibson, Hancock, Knox, Lake, Marion, Newton, Owen, Ripley and Wells counties.

Penstemon laevigatus Ait. This is a common species and I have it from Adams, Bartholomew, Blackford, Delaware, Dubois, Elkhart, Fountain, Gibson, Grant, Jackson, Jefferson, Jennings, Knox, Lake, Madison, Marion, Martin, Orange, Owen, Posey Randolph, Ripley, Scott, Shelby (Mrs. Chas. C. Deam), Spencer, Vanderburgh and Wells counties.

Penstemon pallidus Small. I have this from Crawford, Harrison, Monroe and Noble counties.

Gnaphalium decurrens Ives. St. Joseph County, Sept. 12, 1923. No. 39,671. A large colony in dry sandy soil along the roadside one and a half miles east of Granger.

NOTES ON GRASSES.

PAUL WEATHERWAX, Indiana University.

In order better to understand the relationships of the maize plant the writer has for several years carried on a taxonomic study of the grasses as a group, this work necessitating a somewhat thorough examination of the floral structures of many species. In these studies there have been observed a number of characteristics which might significantly be included in descriptions or considered in studies of the evolution and relationships of the grasses. The purpose of this and succeeding papers is to place on record some of these peculiarities.

1. The habitat of *Paspalum repens* Berg.—This plant is abundant along the banks of Eel River at the northern edge of Greene County, Indiana, this marking the most northern occurrence of the species that has been reported for the State. The plants in this location differ from most descriptions of the species in being distinctly terrestrial. This locality has been under observation nearly every year since 1918, and although conditions for growth of the plant in the water are ideal, not a single specimen has thus far been found in the water. They occur rather in shady places, on rich, moist sandbars, five or six feet above the ordinary level of the water at this season. The plants are more erect than those seen elsewhere in the typical habitat, and the sheaths are little or not at all inflated.

2. Laminate lemmas in *Phleum pratense* L.—On a hill near the Indiana University waterworks reservoir, northeast of Bloomington, Indiana, there have been observed in September and October for four or five years, timothy plants whose inflorescences are more or less rough and leafy in appearance. Examination of these shows that the lemmas of many of the spikelets have well developed leaf blades and ligules. The flowers of these spikelets seem to be normal, and partly developed seeds have been found in a number of them.

In the cases observed, several spikelets were missing from the lower part of each abnormal inflorescence, the mutilation resembling the work of grasshoppers. The presence of numerous bacteria in the minute yellowish exudations from the scars left by the removal of these spikelets, however, suggests the possibility of a diseased condition, which might also account for the unusual development of the lemmas.

Cases similar to this have been reported for other grasses. Britton and Brown[1] note that in arctic regions and in the mountains of New England there is found the so-called variety *vivipara* of the species *Festuca ovina* L., "with the scales wholly or partly transformed into small leaves." Kerner and Oliver[2] mention several, chiefly arctic, "viviparous" grasses, in which small plants develop in the spikelets. Collins[3] has reported a similar occurrence in maize. This anomaly in timothy is probably an expression of the same tendency of floral struc-

[1] Illustrated Flora, 2d Ed., Vol. 1, p. 271, 1913.

[2] Natural History of Plants, 2:818-820, 1895.

[3] Contributions from the National Herbarium, 12:453-456, 1909.

tures to revert to a vegetative condition. A detailed comparison of these different grasses showing the anomaly would make an interesting study.

3. Sex in the sporophyte of *Eragrostis hypnoides* (Lam.) B.S.P.—This species, which is a prominent part of the floras of muddy sandbars in late summer, is generally described as dioecious, and as such it was thought to offer promising material for experimental work. However, an examination of several hundred specimens from three localities in Indiana, and one in Georgia, showed not a single imperfect-flowered specimen. In the variety *capitata* of this species there is said to be a pronounced difference between the staminate and pistillate spikelets, but no specimens of this have been available for examination.

Duplicates of the specimens of Paspalum and Eragrostis upon which these notes are based were identified by A. S. Hitchcock.

PLANTS OF WHITE COUNTY—VI.

LOUIS F. HEIMLICH, Purdue University.

The following is a list of 53 additional species and varieties of the White County, Indiana, flora. This makes a total of 440 species of wild plants of the county reported by the author. The collection dates were June 1 and August 22, 23, and 24, 1923.

In the list given below the grasses were identified by Agnes Chase of the Bureau of Plant Industry, Washington, D. C. All other species with the exception of numbers 840, 855, 870, and 900, were identified by C. A. Weatherby of the Gray Herbarium, Harvard University. A number of specimens of greater interest and the ones as recorded as new to the state or rare have been reviewed by C. C. Deam of Bluffton, Indiana.

It is believed that the following seven species and varieties included in the general list below are new to the state or are of rare occurrence.

Potamogeton americanus C. & S. var. *novaeboracensis* (Morong) Benn. No. 864. Collected in Tippecanoe River just north of the dam at Monticello, east side, Aug. 23, 1923. New record.

Polygonum ramosissimum Michx. forma *atlanticum* Robinson, (*Polygonum atlanticum* Bicknell). No. 858. Collected along the Monon Railroad, north of Reynolds, near Little Honey Creek bridge, Aug. 22, 1923. New record. See figure 2.

Potentilla canadensis L. var. *simplex* (Michx.) T. & G. No. 830. Collected in alley, east part of Reynolds, June 1, 1923. New record. See figure 1.

Geum virginianum L. var. *Murrayanum* Fernald. No. 854. Collected along bank of Little Honey Creek, near Monon Railroad bridge, Aug. 22, 1923. New record. See figure 3.

Rubus flagellaris Willd. (*Rubus procumbens* Muhl.) No. 831. Common in a dry sandy field, east part of Reynolds. Collected June 1, 1923. New record. See figure 4.

Baptisia bracteata (Muhl.) Ell. No. 836. Collected along Pennsylvania Railroad, east of Reynolds, June 1, 1923. Growing on high, sandy soil. According to Deam this is a rare plant, heretofore reported only from Steuben County, but lately collected by Deam in Lake, Porter and Laporte counties.

Helianthus petiolaris Nutt. No. 868. For years I have seen this species growing on dry sandy soil to the east of the dam at Monticello and did not suspect that it was a rare plant in our state. It is a western species and apparently has only been noted twice before in two western counties of the state (Tippecanoe and Lake). See figure 5.

SPARGANIACEAE.

Sparganium eurycarpum Englem. Broad-fruited bur-reed. No. 855.

NAJADACEAE.

Potamogeton americanus C. & S. var. *novaeboracensis* (Morong.) Benn. Variety of the long-leaved pondweed. No. 864.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

15—27933

HYDROCHARITACEAE.

Vallisneria spiralis L. Eel grass or tape grass. No. 879.

Fig. 1. (Left) *Potentilla canadensis* L. var. *simplex* (Michx.) T. & G. Variety of the Five Finger.

Fig. 2. (Right) *Polygonum ramosissimum* Michx. forma *atlanticum* Robinson. (*P. atlanticum* Bicknell). Atlantic Coast Knotweed.

GRAMINEAE.

Andropogon furcatus Muhl. Forked beard-grass or big blue-stem. No. 846.

Spartina Michauxiana Hitchc. Tall marsh-grass or bull-grass. Nos. 847, 860.

Bromus purgans L., var. *incanus* Sheer. Variety of the hairy wood chess. No. 875.

Elymus virginicus L. Terrell-grass or Virginia wild rye. No. 856.

Elymus canadensis L. Nodding wild rye. No. 902.

CYPERACEAE.

Scirpus americanus Pers. Three-square or chair-maker's rush. No. 892.

PONTEDERIACEAE.

Heteranthera dubia (Jacq.) MacM. Water star-grass. No. 884.

URTICACEAE.

Humulus Lupulus L. Common hop. Along Tippecanoe River at Norway. No. 890.

Boehmeria cylindrica (L.) Sw. False nettle. No. 853.

POLYGONACEAE.

Rumex altissimus Wood. Tall or peach-leaved dock, or pale dock. No. 886.

Polygonum ramosissimum Michx. forma *atlanticum* Robinson. (*Polygonum atlanticum* Bicknell.) Variety of the bushy knotweed or Atlantic Coast knotweed. No. 858. See figure 2.

Polygonum hydropiperoides Michx. Mild water pepper. No. 849.

AMARANTHACEAE.

Acnida tuberculata Moq. Rough-fruited water-hemp. No. 891.

CARYOPHYLLACEAE.

Lychnis alba Mill. White campion or evening Lychnis. No. 850.

NYMPHAEACEAE.

Nymphaea advena Ait. Large yellow pond lily. No. 840. With the disappearance of sloughs and ponds of the county, this species is practically restricted to the Tippecanoe River.

RANUNCULACEAE.

Clematis virginiana L. Virginia virgin's bower or woodbine. No. 881. Native vine, growing along Tippecanoe River near Norway.

CRASSULACEAE.

Sedum acre L. Wall pepper or mossy stonecrop. No. 905. Escaped in a yard, north part of Reynolds.

SAXIFRAGACEAE.

Ribes aureum Pursh. Missouri or buffalo currant. No. 871. Escaped.

Ribes americanum Mill. Wild or black currant. No. 859. Along banks of Little Honey Creek east of Monon Railroad bridge and several other places.

ROSACEAE.

Pyrus melanocarpa (Michx.) Willd. Black chokeberry. No. 833.

Potentilla canadensis L. var. *simplex* (Michx.) T. & G. Variety of the five finger or common cinquefoil. No. 830. New record. See figure 1.

Geum virginianum L. var. *Murrayanum* Fernald. Variety of the rough avens. No. 854. New record. See figure 3.

Rubus flagellaris Willd. (*Rubus procumbens* Muhl.) Low running blackberry or dewberry. No. 831. Common on poor sandy soil. Badly rusted. New record. See figure 4.

LEGUMINOSAE.

Baptisia bracteata (Muhl.) Ell. Large-bracted wild indigo or yellow false indigo. No. 836. Dry sandy soil, rare.

Melilotus officinalis (L.) Lam. Yellow sweet clover. No. 861.

Medicago sativa L. Alfalfa or purple medic. No. 843. Escaped.

Fig. 3. *Geum virginianum* L. var. *Murrayanum* Fernald. Variety of the Rough Avens.

Desmodium marilandicum (L.) D.C. Smooth small-leaved tick-trefoil. No. 894.

Apios tuberosa Moench. Ground-nut or wild bean. No. 865.

EUPHORBIACEAE.

Acalypha gracilens Gray. Slender three-seeded mercury. No. 898.

Euphorbia Cyparissias L. Cypress spurge. No. 869. Escaped.

VITACEAE.

Psedera quinquefolia (L.) Greene. Virginia creeper. No. 895.

HYPERICACEAE.

Hypericum perforatum L. Common St. John's wort. No. 885.

Hypericum cistifolium Lam. Round-podded St. John's wort. No. 845.

LYTHRACEAE.

Rotala ramosior (L.) Koehne. Tooth-cup. No. 877. Near Buffalo Bathing Beach.

ONAGRACEAE.

Gaura biennis L. Biennial gaura. No. 889.

Fig. 4. *Rubus flagellaris* Willd. (*Rubus procumbens* Muhl.) Low Running Blackberry or Dewberry.

UMBELLIFERAE.

Cryptotaenia canadensis (L.) D.C. Honewort. No. 874.

OLEACEAE.

Syringa vulgaris L. Common lilac. No. 870. Escaped along fence rows or remaining and spreading at sites of old homesteads.

ASCLEPIADACEAE.

Acerates hirtella Pennell. (*A. floridana* (Lam.) Hitchc. in part). No. 844. Common north of Reynolds.

Fig. 5. *Helianthus petiolaris* Nutt. Prairie Sunflower.

LABIATAE.

Scutellaria canescens Nutt. Downy skullcap. No. 876.

Agastache nepetoides (L.) Ktze. Catnip giant-hyssop. No. 873.

Mentha arvensis L. var. *glabrata* (Benth.) Fernald. Variety of the corn or field mint. No. 880. This variety has been usually reported under the name of *Mentha canadensis* L.

SCROPHULARIACEAE.

Verbascum Blattaria L. Moth mullein. No. 842.

ACANTHACEAE.

Dianthera americana L. Dense-flowered water-willow. No. 888.

Ruellia ciliosa Pursh. Hairy or longtube Ruellia. No. 882.

PLANTAGINACEAE.

Plantago Rugellii Dcne. Rugel's or pale plantain. No. 900.

Plantago aristata Michx. Large-bracted plantain. No. 899.

CUCURBITACEAE.

Echinocystis lobata (Michx.) T. & G. Wild cucumber. No. 852.

COMPOSITAE.

Helianthus petiolaris Nutt. Prairie sunflower. No. 868. For a number of years growing on dry sandy soil, east of dam at Monticello. Rare in Indiana. See figure 5.

Cichorium Intybus L. Common chicory or blue sailors. Nos. 866, 893. At dam, Monticello, and also northwest of Reynolds, growing in dry sandy soil.

INDIANA FUNGI—VII.

J. M. VAN HOOK, Indiana University.

The plants described in this seventh paper on "Indiana Fungi", have been collected, for the most part, during the seasons of 1922 and 1923. Though we are still concerned in listing all species new to us, new to the state and new hosts, we are now primarily concerned in making additions to present descriptions or in some instances, even completely redescribing the species in the light of better material, finding it extremely important to make collections throughout the season rather than to be content with a single collection. The color and size of spots and the host plant are often constantly changing. Our hope is that we may not only be of assistance in reducing the number of species names, but by extending our descriptions, to prevent some new species from being named unnecessarily. It is very evident that the things left unsaid in the so-called "one line descriptions", have been utilized too freely in selecting characteristics for certain new species. It is a great source of satisfaction to mycologists to note that our most recent new species descriptions are very complete.

Indiana offers one of the most fertile fields in the United States for the study of fungi. Many of the wooded valleys of southern Indiana, rich in the Agaricaceae, await the student of that group. Much of our forest area is still in a primeval condition as far as fungi are concerned, and many undescribed species still exist. Donaldson Farm, now a part of Indiana University, retains all of its largest trees both living and dead and therefore offers what is now the best forest collecting ground in Indiana.

PHYCOMYCETES.

Plasmopara Geraniae (Pk.) Berl. & De Toni. On living leaves of *Geranium maculatum*, Campus of Indiana University, June 1, 1922. Collected by Adams. No. 3920.

Peronospora parasitica (Pers.) De Bary. On living *Lepidium Virginicum*, where it is especially noticeable in rings around the stems. Coll. Weatherwax. May 18, 1922. 3919. Monroe County.

ASCOMYCETES.

Calosphaeria princeps Tul. On dead peach limbs. Orange County, January 1, 1921. McIntosh. 3798. Fruit bodies seated beneath outer bark on layers of inner bark.

Caryospora putaminum (Schw.) DeNot. On old peach pit on ground, May 17, 1923. Monroe County. 3945.

Coccomyces Kerriae Stewart. On living stems and leaves of *Kerria Japonica*, Campus, 1923. Kay. The conidial stage of this fungus which is a *Cylindrosporium*, appeared on the foliage early in July causing defoliation. It immediately appeared as black blotches on the canes where it persists. According to Stewart, the ascus stage develops on these stems. (Phytopathology VII, pp. 399 to 407, 1917.) So far as we know, this is the first appearance of the

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

fungus on the campus though no new shrubs of this species have been planted for fifteen years.

Epichloe typhina (P.) Tul. On living *Sphenopholis pallens*, Campus, 1922. The conidial stage was first found May 18, and the ascus stage on June 26. Etter. 3917.

Erysiphe Polygoni DC. (*E. Liriodendri* Schw.) On fallen leaves of *Liriodendron tulipifera*, October 23, 1921. The mycelium of this fungus was very conspicuous. 3886.

Exoascus Pruni Fckl. On fruits of plum, forming bladders. G. W. Blaydes. 1922. Putnam County. 3944.

Gnomonia veneta (Sacc. & Speg.) Kleb. On leaves and twigs of *Platanus occidentalis*, Orange and Lawrence counties, May 13, 1922. 3918. All twigs on many trees were killed in these and Monroe counties in the spring of 1922. The conidial stage, *Gloeosporium nervisequum* (Fckl.) Sacc. appears at this time.

Guignardia Aesculi (Pk.) Stewart. (See *Phyllosticta Paviae* Desm.)

Hypoxylon rubiginosum (Pers.) Fr. On decorticated log of *Liriodendron tulipifera*, Borden, Clark County, October 20, 1922. 3934. This is both a new host and a new county for this fungus.

Nummularia discreta (Schw.) Tul. On dead branches of *Ulmus americana*, Orange County, January 1, 1921. McIntosh. 3802. Although this fungus is very common on apple where it is productive of a serious canker disease, this is the first time we have noticed it on elm.

Rhytisma punctatum (Pers.) Fr. On living leaves of *Acer saccharinum*, Harrodsburg, Monroe County, October, 1921. J. K. Van Hook. 3893. On *Acer nigrum*, Campus, Monroe County, 1922. Anderson. 3938.

Sclerotinia cinerea (Bon.) Schroet. On plum mummies, Putnam County, April 15, 1922. Blaydes. 3916.

Sphaerospora confusa Cke. On burnt ground, Bean Blossom Valley, Monroe County, July 16, 1923. Anderson and Bell. 3960.

Xylaria subterranea (Schw.) Sacc. On old wood taken from Donaldson's Cave, July 16, 1923. Hawkins. 3958.

BASIDIOMYCETES.

USTILAGINALES.

Entyloma compositarum Farl. On basal leaves of *Senecio obovatus*, Harrodsburg, Monroe County, April 30, 1922. 3913. Especially destructive to young leaves. On the same host, State Park, Owen County, May 1, 1922. 3914.

UREDINALES.

Kuhneola obtusa (Strauss) Arthur. Uredo stage abundant on *Potentilla canadensis*, State Park, Owen County, May 1, 1922. Adams. 3915.

Puccinia Silphii Schw. On living stems of *Silphium perfoliatum*, near Owensburg, Greene County, July 14, 1923. Hawkins. 3963.

AGARICACEAE.

Clitocybe multiceps Pk. J.R.S. Scott, Lawrence County, July 31, 1923. 3968.

Lentinus lepideus Fr. On living *Picea excelsa*, City Cemetery, Monroe County, May 30, 1922. 3921. Gills somewhat narrower than usually given in descriptions. Perhaps not well developed.

Panus torulosis Fr. On rotten wood, Monroe County, May 21, 1923. 3946. Some of the young stems of this edible species are a beautiful pallid violet to aniline lilac.

Pleurotus sapidus Kalchbr. On *Quercus* log, Monroe County, December 14, 1921. Hudelson. 3911. One specimen with pileus more than thirteen inches broad. Spores pale grayish vinaceous to light grayish vinaceous. Beautiful spore-prints were obtained from this specimen and exposed to strong light for one year. Only slight fading was apparent.

Pleurotus serotinoides Pk. On *Ulmus americana*, December 1, 1921. Hudelson. Monroe County. 3910.

Volvaria bombycina (Pers.) Fr. On living maple, Lawrence County. Scott. 3967.

POLYPORACEAE.

Polyporus delectans Pk. On dead *Acer* two feet from ground, Orange County, October 10, 1920. McIntosh. 3792.

CLAVARIACEAE.

Sparassis crispa (Wulf.) Fr. On ground, Bean Blossom Valley, Monroe County, July 18, 1922. Hudelson. 3927. A most delicious edible species.

FUNGI IMPERFECTI.

SPHAEROPSIDALES.

Actinonema Tiliae Allesch. On living leaves of *Tilia americana*, Winona Lake, Kosciusko County, August 22, 1921. 3894.

Byssocystis tevtilis Riess. Parasitic on powdery mildew of *Plantago Rugelii*. Monroe County, 1922. This rare species was found while identifying *Ramularia Plantaginis* Pk. which was taken from the same leaf. The fungus corresponds exceptionally well with description except that the pycnidium was about 50 by 35 microns. Conidiophores apparently present and intercalary spores two-celled.

Discosia artocreas (Tode.) Fr. On leaf spot of *Poenia officinalis*. Spots apparently caused by an undescribed species of *Septoria*. Monroe County, July 20, 1923. 3964. Found also on leaves of *Prunus serotina*, July 28, 1923. McKay. Monroe County. 3965.

Phyllosticta commonsii E. & E. On living leaves of *Paeonia officinalis*, Monroe County, July 17, 1923. 3962. Agrees well with the description, except that of the spores which are given as 4 to 5 (exceptionally 6 to 7) by 2 to 2.5 microns. (See Journal of Mycology, Vol. V, pp. 146. 1889.) In our specimens, the spores are decidedly greenish yellow in mass and measure 5 to 7.5 by 3.5 to 5 microns.

Phyllosticta cornicola (DC.) Rabh. On living leaves of *Cornus florida*, Owen County, July 15, 1923. 3961. The pycnidia, which are given by Saccardo as 150 to 200 microns and by Ellis and Everhart as 80 to 100, measure here 65 to 85. The pycnidia have definite pores 7.5 to 12.5 microns in diameter. The spores agree with measurement given by E. & E. They are granular.

Phyllosticta Labruscae Thuem. On living leaves of *Ampelopsis tricuspidata*, Monroe County, June 14, 1920. 3801.

Phyllosticta melaleuca E. & E. On living leaves of *Ulmus americana*, Monroe County, July 13, 1923. Hawkins. 3957. This species, described in North American Phyllostictas, p. 43, in 1900, was apparently not placed in Saccardo. The spots are small and circular. Pycnidia, 75 to 150, with pore 25 to 30. Spores, 2.5 to 3 by 5 to 6, elliptical, dark olive and appearing dark yellow in mass. Very numerous. A close observation of our specimens suggests a *Coniothyrium* rather than a *Phyllosticta*.

Phyllosticta minima (B. & C.) E. & E. On living leaves of *Acer rubrum*, Kerr Creek, June 22, 1922. 3783. Griffey Creek, June 18, 1923. 3947. Also on *Acer saccharinum* on small bushes mixed with number 3947, and on the latter host on small bushes near ground on the Campus. 3949. This is one of our most common leaf diseases and abounds in early June on maples particularly on north hillsides. This species seems to be identical with *P. acericola* C. & E. Our description which varies somewhat with the original is as follows: *Spots* usually few and small, 1 to 5 mm. in diameter, sometimes larger or by confluence spreading over a large portion of the leaf, circular or angular, olive brown to sepia above, with small (1 mm.) pale center, hair brown below; *pycnidia* almost wholly epiphyllous, scattered over the entire spot but not occurring to any extent in the light-colored center of the spot, 65 to 120 microns, usually about 90, with a distinct pore averaging 12.5 in diameter; *spores* 5 to 7 by 8 to 10, ovate, elliptical or subspherical (tending to angular sometimes when dried) granular, hyaline and surrounded by a thin coat of slime.

Phyllosticta Paviae Desm. On leaves of seedlings of *Aesculus glabra*, Marion County, April 30, 1921. 3897. Monroe County, August 1, 1920. 3820. This is among our earliest Imperfects to develop and should be collected in the early spring months to assure the finding of an abundance of spores. It is occasionally quite destructive to the leaves of small plants. (See specimen number 97, Underwood's Indiana Flora, collected in Brown County. For a detailed account of this species, see Phytopathology, VI, pp. 5 to 19, by V. B. Stewart.)

Phyllosticta solitaria E. & E. On leaves and fruit of apple, Monroe County, August 1, 1922. 3929. July 4, 1923. Hawkins. 3956. The single, or at most, two or three pycnidia, in all examinations made (upon leaves from specimen 3956) contained spores. According to Ill. Circ. 241, "Within the spots on the leaves pycnidia are formed, but according to most authorities remain sterile, that is, no spores are produced". The small spots on leaves are often triangular, quadrilateral, etc., determined by leaf veins which limit them. Our spores from fruit and leaves are 8 to 10 by 5 to 7 making them broader than usually given. The pycnidia range from 75 to 100. Pore, 10 to 13, in diameter. Within the past decade, this has gradually become one of the most important apple diseases in this section of Indiana, where it does great injury to leaves, fruit and

twigs. In some unsprayed orchards, every fruit on certain trees was cracked open on account of it.

Septoria erigerontis B. & C. Monroe County. 1923. 3969. One of our most common parasites. These have pycnidia 100 to 125 microns in diameter; spores, 1.5 to 2 by 30 to 70. These spores evidently never have been carefully measured. *S. erigerontis* B. & C. is said to have spores 38 microns long and those of *S. erigerontea* Pk. are given as 25.

Septoria piricola Desm. On leaves of *Pyrus communis*, Clark County, October 1, 1922. Trees practically defoliated. 3939.

Sphaeropsis malorum Pk. On apple leaves and fruit October, 1920. Common. 3803.

Vermicularia Dematium (Pers.) Fr. On dead spots in leaves of *Fraxinus americana*, August 1, 1923. Monroe County. 3971.

Vermicularia Liliacearum Westend. On living leaves of *Funkia ovata*, July 16, 1920. 3789. On *Convallaria majalis*, July 16, 1920. Kay. Both collected in Monroe County. Spots oval or elongated, spreading indefinitely, border brown, center light; pycnidia globose, oval, or varying in shape and size up to 125 microns in diameter; setae on or around the pycnidia, dark brown, 50 to 100 by 5 to 6, lighter at tips, septate, sometimes bent or enlarged variously at base; spores fusiform, mostly acute, some obtuse, for the most part, curved, usually two guttulate, hyaline, 3 to 4 by 12 to 25 microns.

MELANCONIALES.

Glocosporium nervisequum (Fckl.) Sacc. (See *Gnomonia veneta.*)

HYPHOMYCETES.

Cercospora ampelopsidis Pk. On living leaves of *Ampelopsis quinquefolia*, Lawrence County, July 16, 1922. 3925.

Cercospora canescens E. & M. On living leaves of Lima bean, Clark County, October 1, 1922. 3931. On common bean, *Phaseolus vulgaris*, Monroe County, July 30, 1923. 3973. Since our specimens vary somewhat from the original description, a redescription is added for Lima bean. Spots on dried leaf, fading out and becoming paler in center, circular or irregular, 1 to 10 mm. in diameter, very numerous, sometimes showing concentric rings, often coalescing and covering large areas finally killing the leaves; below, the spots about as evident, but not becoming so pale in the center. Conidiophores amphigenous, brown, straight or curved, sometimes nodulose, 50 to 275 microns long, slightly tapering above and some paler at tip. Spores straight or curved, hyaline, 5 to 20 or more septate, 3 to 5 by 100 to 225.

Cercospora cercidicola Ell. On living leaves of *Cercis canadensis*, Monroe County, June 22, 1923. 3972. This specimen varies from the description as follows: Conidiophores 100 to 150 by 4 to 5, bearing several spores, fasciculate character noticeable, the lower half frequently forming a column; spores yellowish, 18 to 55 by 4 to 6, one to three septate, when typically developed about 50 by 5 and two septate.

Cercospora flagellaris E. & M. On living leaves of *Phytolacca decandra*, Monroe County, July 28, 1923. Kay. 3966. Our specimens show conidiophores to 150 by 4 to 6; conidia 40 to 175 by 3 to 5, and to 12 or more septate. They are described as being 8 to 10 septate. They should be described as being pluri-septate.

Cercospora Noveboracensis E. & E. On living leaves of *Vernonia Noveboracensis*, Monroe County, September 10, 1921. 3888. This fungus defoliates the plants at the base advancing upward. Agrees well with the description, except: Spots very definite, brown, with dark purplish border, circular or angular, to one cm. in diameter, on old leaves spreading more indefinitely, or even without spots. Spores 3 to 5 by 20 to 70, wider than described, and many tapering above as is characteristic of the genus.

Cercospora oculata E. & E. On living leaves of *Vernonia*, Monroe County, July 1, 1923. 3954. In our specimens, conidiophores 25 to 30 by 4 to 5, curved, nodulose or serrate at tip, olive; spores continuous to five septate (mostly three septate), long elliptic to attenuate according to size of spore, sometimes with tapering truncate base, 15 to 55 by 5 to 7. On leaves with a *Stagonosporium* which makes similar spots.

Cercospora Ribis Earle. On *Ribes rubrum*, defoliating them, Clark County, October 20, 1922. 3932.

Cercospora Rubi Sacc. On living leaves of *Rubus*, Clark County, October 20, 1922. 3935.

Cercospora Sanguinariae Pk. On living leaves of *Sanguinaria canadensis*, Lawrence County, July 4, 1922. 3923. Agrees unusually well with the description. Our material shows spores 35 to 70 by 3 to 4 and many 3-septate. Some taper from enlargement above base as is typical of the genus.

Ramularia Brunellae E. & E. Agrees well. Addition to description: Conidiophores sometimes arising from a dark-colored tuberculate partly immersed base. Spores 6 to 17 in length, sometimes guttulate at the center giving the appearance of a septum. (See Jour. Mycol. 1889, p. 69.)

Ramularia decipiens E. & E. (Jour. Mycol., Vol. I, p. 70.) On *Rumex obtusifolius*, Monroe County, October 20, 1920. 3817. In this material the spots are numerous, brown, with small white centers, and surrounded by a greenish purple border. The spores are mostly 12 to 25 by 4 to 6, continuous, becoming 1-septate, slightly truncate at point of attachment. This species is very common in this county.

Ramularia Plantaginis Pk. On *Plantago Rugelii*, Putnam County, June 27, 1922. Blaydes. 3942. The fungus was here associated with *Byssocystis textilis* described herein.

MYXOMYCETES.

Physarum nefroideum Rost. On dead leaf of *Acer saccharinum*, June 22, 1923. Anderson. 3951.

CULTURE METHODS IN THE PRODUCTION OF POLYEMBRYONY IN CERTAIN FERNS (POLYPODIACEAE).

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To Secure the Stock Culture.—In both stock and transplanted cultures the prothallia are grown upon rich soil, preferably woods earth. Unglazed earthen ware vessels, flower pot saucers, are used as containers.

The thoroughly moistened (not wet) soil is passed through a sieve with one-fourth inch mesh. First a thin layer of coarser earth is placed in the saucer, which is then filled three-fourths full with the sifted earth. Upon this is evenly spread a thin layer of earth which has been passed through a finer sieve such as may be made from fly screen wire. The surface is then gently firmed with the hand, so that an even and sufficiently compact surface is provided. A moat is now made around the edge by pressing the soil back from the side of the saucer with a stick or finger.

The vessel with the soil thus prepared is sterilized in a steam sterilizer two hours on each of two successive or alternate days. If the soil be too wet before sterilization, the result will be a mud pie instead of a suitable substratum.

The soil is now evenly coated with the spores, and the culture covered with a belljar. It is well to prop up the belljar on one side to a height of about one-fourth inch to insure ventilation and to facilitate evaporation should the culture be made too wet in watering. The soil is kept moist by sub-irrigation, the water being gently poured into the moat. This method is preferred to that of allowing the saucer to stand temporarily in shallow water. Cultures should never be watered by spraying, and care should be taken not to keep the soil wet.

Good diffused light provides the best illumination. However, direct sunlight for an hour in early morning is beneficial.

Transplanting and Cultivation.—The soil is prepared as for the stock culture, and the conditions are to remain the same.

When the prothallia are from one to three millimeters in breadth, or larger, they are lifted from the stock culture with needle or forceps, along with sufficient earth to preserve the majority of the rhizoids, and set out in the new dish about an inch apart. Care should be taken to remove all smaller adhering prothallia. The soil should be quite moist at the time of transplanting so that the earth about the rhizoids may be pushed easily into it. The under free surface of the prothallium should not come into direct contact with the soil. If after a time weed-prothallia, mosses or other plants appear in the cultures, these should be removed. If the surface of the soil should become caked or grown over with blue-green or other algae, as may happen in long-standing cultures, the earth should be allowed to dry somewhat and the caked or matted surface removed and fresh sterilized soil added. Sometimes it is desirable to transplant the prothallia to newly prepared culture dishes. They should be lifted with enough earth to preserve the

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

rhizoids. Growing prothallia for longer periods of time than obtains under natural conditions out of doors, however, requires experience to insure success.

Fertilization or Fecundation.—When the plants have attained the desired size—eight to ten millimeters in width—fecundation should be begun. If the prothallia be monoecious, three or four drops of water are allowed to fall upon the growing notch. It is better to do this near mid-day when the cultures are a little drier, as the mature archegonia will then open readily, and at the same time sperms will escape from the antheridia. This procedure should be repeated every other day for a few times, so that several egg cells may be fecundated upon a given prothallium.

If the prothallia tend to be dioecious, as in *Onoclea sensibilis* and *Matteuccia Struthiopteris* (*Onoclea Struthiopteris*), it is well to place a small tuft of male plants close to the apical sinus before dropping on the water, in order to insure fecundation.

NOTES ON GREENHOUSE CULTURE METHODS USED IN RUST INVESTIGATIONS.[1]

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The methods necessary for the production of infections with rusts are relatively simple. Yet, the more intensive and detailed studies, especially in connection with specialized strains and physiological relations, have necessitated certain refinements. These are being developed in various ways in laboratories where such investigations are conducted. In the investigation of the leaf rusts of wheat, *Puccinia triticina* Eriks., rye, *P. dispersa* Eriks., barley, *P. simplex* (Körn) Eriks. & Henn., and corn, *P. Sorghi* Schw., in progress at the Purdue University Agricultural Experiment Station, co-operating with the Office of Cereal Investigations, of the Bureau of Plant Industry, U. S. Department of Agriculture, since 1918, it has been necessary to modify certain established culture methods to meet conditions peculiar to the problem.

This paper has been written primarily with the object of describing such modifications. However, with the idea that it might be made more generally useful, especially for students desiring to undertake some culture work in laboratories where little or no rust research is carried on, descriptions of these modifications, together with reference to methods developed in other laboratories, are incorporated in an account of the general culture procedure employed in this laboratory. This procedure is believed to be similar to that used in most other laboratories where such studies are in progress. Descriptions of rust-culture methods have been published in numerous journals and bulletins dealing with the results of investigations of many different species of rusts. Papers by Carleton (1903),[2] Melhus (1912) and Fromme (1913), however, deal primarily with culture methods for this group of parasites.

1. Collection and Storage of Inoculum. Spores for inoculation purposes are relatively easily obtainable. Where the aecia or uredinia occur locally, rusted plants are brought into the laboratory and sowings are made with the fresh spores. When the problem involves the study of a rust from various sections of the country as for example the investigation of the occurrence and characteristics of different strains of *Puccinia triticina*, the fungus causing the leaf rust of wheat, the inoculum may be in transit several days. In the case of this rust, and many of the grass rusts, the spores will remain viable several days if rusted leaves simply are placed in heavy Manila envelopes and mailed.

It is a mistake to tightly wrap rusted plants in moist or paraffin paper in order to prevent desiccation. Under such conditions, especially during hot weather, more or less heating, fermentation, and molding of the material takes place, which is very detrimental to the viability of

[1] Contribution from the Botanical Department of the Purdue University Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, co-operating.

[2] Reference, by date, to "Literature Cited."

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the spores. This has been found to be especially true in the case of the aecia of the leafrust of wild grasses, *Puccinia Clematidis*. If the latter are gathered when thoroughly mature, they can be sent long distances, drying out on the way, and satisfactory cultures may be obtained in most cases. Aeciospores of *Puccinia Impatientis* have been dried rapidly for two days in a plant press heated to a temperature of 27° C., and excellent germination obtained from them. Aeciospores of this same species also have given good germination after dry storage in a packet at room temperature for 25 days. Aeciospores of *Puccinia triticina*, similarly kept, gave excellent germination at the end of 5 days, a slight percentage of germination still being obtained at the end of 28 days.

Uredinial material of *Puccinia triticina* has been sent by mail from many points over the United States and no difficulty has been experienced in obtaining good cultures. Wheat leaves infected with this rust were collected in 1923 at Hanford, Calif., on June 7; Knoxville, Tenn., June 12; Washington, D. C., June 16; Harmony, Wash., June 21; Urbana, Ill., June 27; Bloomington, Ill., July 5; Wanatah, Ind., July 9; Madison, Wis., July 23; and St. Paul, Minn., on July 24, and mailed to Lafayette, Ind., as described above. They were kept in an ice-box at approximately 9 to 12° C., until Nov. 13, when sowings were made from them on wheat, a fair amount of infection being obtained in each case. In other words, urediniospores of *Puccinia triticina*, 159 days after collection, were still able to give infection.

On Jan. 26, 1921, urediniospores of *Puccinia Sorghi* and *Puccinia triticina* were collected from greenhouse material and distributed in small cotton-stoppered vials at temperatures of 10, 15, 20, 25, 30 and 35° C., and outdoors. The germination of these was determined at various times until March 1. Both rusts showed a gradual reduction in germination after storage at the higher temperature, 35, 30, 25° C. About the same or slightly less germination was maintained at 20, 15, 10° C., while spores stored outdoors showed even better germination on March 1, when last examined. Peltier (1922) has investigated this question extensively for *Puccinia graminis*. Fromme (1913), Melhus and Durrell (1919), Peltier (1922), and Doran (1922) give data obtained by themselves and other investigators showing that the germinability of aeciospores and urediniospores of a number of species of rusts may be retained from 30 to 112 days. In general, germinability is retained longest at lower temperatures. Storing these spores dry at the cool temperature and moderate humidity of a refrigerator, either on the dry host or in vials, may be a useful method of carrying rusts over the summer, when it is not desirable or impossible to carry on investigations because of high greenhouse temperatures.

Teliospores may be collected and mailed in a similar manner. As in many species these are resting spores, the usual difficulty is not to prevent loss of viability but to bring about germination. The viability of the teliospores of those species which germinate at once may be prolonged, however, by refrigeration. Those which usually germinate only after overwintering are hung out of doors in cheesecloth bags within a foot or so of the ground. In this way, they are brought into a ger-

minable condition in the spring when their alternate hosts are in the best condition for infection.

2. Germinability of Spores. In general, aeciospores and urediniospores are capable of germinating when they naturally become detached from the spore chain or pedicel, spores not germinating being considered either immature or too old. A number of the rusts under investigation in this laboratory, however, have given only fair to moderate germination of urediniospores under conditions which indicate other factors of importance. Urediniospores of *Puccinia Sorghi* and *Puccinia triticina*, collected from greenhouse material on Jan. 26 and Feb. 1, 1921, and stored out of doors in vials, showed an increase in germination when tested Feb. 11 and March 1. We have found that drying for several days greatly increases germination of such spores. Melhus and Durrell (1919) have noted a similar condition for the urediniospores of *Puccinia coronata*. They found that storage of these spores in vials resulted in a marked increase in germination, indicating a maturation of the spores, even after detachment from the pedicel. It is very likely that the conditions under which these spores are formed have an important bearing upon their viability. But little seems to be known concerning this question.

On the other hand, the factors bringing about germinability in teliospores have received more attention. This probably is due to the fact that the teliospores of many species function as resting spores and usually are germinable only after weathering, generally over winter. This has stimulated investigation as to the factors concerned. Klebahn (1914), Maneval (1922), and the writer (1916) have shown that the teliospores of such species may be brought into a condition for germination by alternate wetting and drying or by more or less prolonged soaking without exposure to winter conditions. Thiel and Weiss (1920) have been able to bring about a condition for germination by treatment of teliospores of *Puccinia graminis* with citric acid. These methods may be found helpful in some investigations, as teliospores made germinable in the fall or early winter enable work to be carried on at a time of year when greenhouse conditions are more easily controlled. However, if the alternate host is a perennial, complications are introduced, as it will be necessary to bring it out of its resting period and into a vigorous growing condition.

That, even in nature, conditions sometimes may occur which bring about a considerable deviation from the typical situation, was noted in 1920. Thus two collections of *Puccinia montanensis* Ellis, two of *P. Koeleriae* Arth., five of *P. Clematidis* (DC.) Lagerh., eight of *P. procera* Dietel and Holw., three of *P. apocrypta* Ellis and Tracy, and fourteen of *P. triticina* showed teliospores germinating vigorously when brought into the greenhouse on Dec. 10 and tested. Collections of teliospores of these species tested the two previous seasons during the fall gave no germination and it has been generally considered that the teliospores of these species are germinable only after overwintering. All of the above collections were placed outside again and overwintered, and seventeen of them were still germinable when tested during March. On the other

hand, teliospores of a species which usually gives germination the fall of the year in which they mature also may germinate the following spring. In such a rust, *Puccinia dispersa*, twelve collections showed teliospores germinable between Aug. 19 and Nov. 25, 1919. Two additional collections gave germination in December. Of these 14 collections, five still gave germination the following spring on April 7, 1920.

3. **Methods of Testing the Germination of Spores.** It is evident that, before inoculating with teliospores, it is of considerable importance to know whether they are germinable. In the case of aeciospores and urediniospores it is not so essential as they usually can be relied on to give some germination from fresh material. With old inoculum, or where the plants to be inoculated are uncertain hosts, it is well to make germination tests in order to give proper value to negative results.

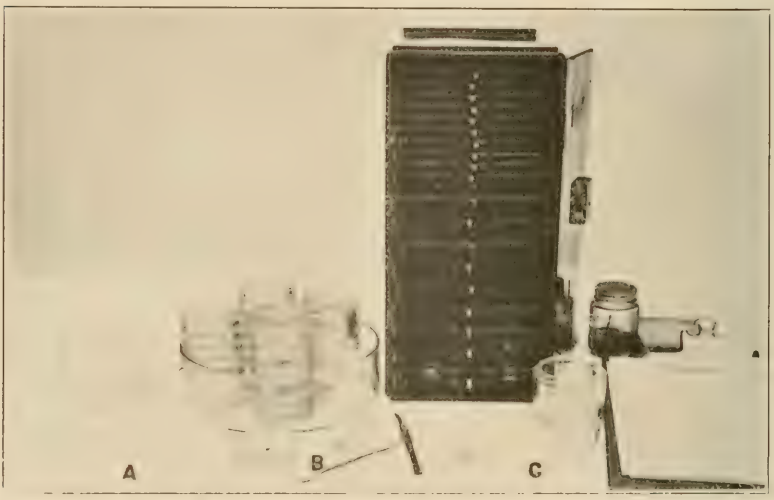

Fig. 1. Methods of testing spore germination. A. Petri dish; B. Syracuse watch glasses; C. Modified Van Tieghem cells.

Several different methods of making spore germination tests have been in use in this laboratory, being more or less modifications of those used by a number of other investigators. Modified Van Tieghem cells (fig. 1, C) were first used. In this method a drop of water is placed upon a cover glass and the spores are added to this drop. Water is placed also in the bottom of the cell which consists of a glass ring sealed onto a glass slide. The cover glass, with drop, is inverted and sealed with vaseline to the upper side of the ring.

A metal microscope-slide case was found very convenient in handling germination tests of 200 to 300 collections of teliospores, made about once a week during the spring months. Every other tray was removed and this gave plenty of room for the Van Tieghem cells, allowing them to be stored in a small space. These cells make easily possible the examination of the spores with the 4 mm. objective of the microscope without disturbing the humidity. Where frequent and numerous tests are

being made this method has the objection that considerable time and work is necessary to prepare the cells and remove the vaseline from the cover glasses in preparation for another test.

A less laborious method is to use Syracuse watch glasses (fig. 1, B) with ground glass margins. The bottom of the watch glass is covered with water on which the aeciospores or urediniospores are floated. The accession number of the collection or other identification mark is written on the ground glass margin. Another dish is placed on top of this in which another collection of spores is tested. A number of watch glasses can be stacked thus and a number of such stacks placed in shallow dishes for convenience in carrying from place to place.

Hanging drops also can be made with these watch glasses by placing the spores in one or more drops of water on the bottom of a watch glass, inverting it and placing it on another inverted watch glass which has been covered with water. The beveled edge of one glass fits into a groove in the bottom of the other so that there is little danger of slipping. The hanging drop is by far the best method with teliospores of *Puccinia triticina*, for they otherwise are likely to sink to the bottom of the drop and either not germinate or give abnormal germination. In this method, however, the drops can be examined to advantage only under the lower powers of the microscope. This method has the advantage of requiring but little time in the preparation and labeling of the tests. Hursh (1922) also has used and described this method.

Still another method is to make hanging drops on the lid of a petri dish, the water in the bottom providing the humidity. Spores have been tested also by placing the drops on glass slides in petri dishes raised above the wet substratum (moistened filter paper or paper toweling) by glass slips (fig. 1, A) as described by Melhus (1915) and Melhus and Durrell (1919). The petri dishes take up somewhat more room than watch glasses, but the latter method has the advantage that a cover glass can be placed on the drop, enabling examination under the higher powers of the microscope. Each method has features of advantage in different types of investigations.

4. Environmental Conditions Governing Spore Germination. As inoculation with the rust fungi depends upon the germination of their spores, the conditions influencing spore germination must be taken into consideration in devising methods for the culture of these fungi. Perhaps the most essential condition is a humidity of 100 per cent. In many rusts, the spores must also be in contact with water. While spores may germinate through a fairly wide range of temperatures, for many rusts a temperature of 16-20° C., is most favorable for germination, few spores germinating below 5° C., or above 30° C. Different species, however, vary somewhat as to the cardinal temperatures for spore germination. Fromme (1913), Doran (1922) and Maneval (1922) give summaries of the results obtained by themselves and other investigators in the studies of the effect of various conditions on the spore germination of a number of rusts.

While these are the principal factors governing germination, still other factors are of some importance in the greenhouse investigations.

One of these is the toxicity of the water. At this laboratory, no detrimental effect has been obtained from the use of tap water. Melhus and Durrell (1919), however, found tap water toxic to urediniospores of *Puccinia coronata* at Ames, Iowa, and used distilled water in their inoculations. Another factor of importance is the submersion of the spores. Aeciospores and urediniospores of *Puccinia triticina* give little or no germination if submerged and the teliospores, if they germinate at all, produce long tubes without forming basidia. This has been noted by a number of investigators (Melhus & Durrell, 1919; Melhus, Durrell & Kirby, 1920; and Doran, 1921).

5. **Inoculation—Urediniospores.** The inoculation method used depends upon the type of investigation being conducted. Where either a few plants are being inoculated, or the amount of inoculum is small, or where different strains of rust are being studied, necessitating carefully controlled conditions, each plant is inoculated with spores applied with a scalpel. The plants are first wet by atomizing with a De Vilbiss atomizer as recommended by Melhus (1912). In the case of the cereals, a waxy coating on the leaves prevents water from adhering. This is overcome by gently drawing the leaves between wet fingers, as recommended by Melchers (1915), until water adheres.

Spores are removed from the rusted plants with a straight-edged scalpel and spread on the wetted leaves. It has not been found necessary to trim the inoculated plants of all leaves except those inoculated and no difficulty has been found in interpreting the results. Inoculations with the leafrusts of wheat, rye, barley, and corn give practically as good results when the spores are placed on one surface of the leaf as on the other. This enables rapid sowing of spores, as a number of plants may be inoculated by holding the leaves by the tips so that they are in one layer and covering them all with spores at the same time. Hungerford and Owens (1923) state that in the case of *Puccinia glumarum* good infection is obtained only when spores are sown on the upper side of the wheat leaf. Melchers (1915) recommends the sowing of *Puccinia graminis* on the lower side of the leaf. Where more than one culture of the same rust is being studied the usual precautions of sterilizing the instruments used must be taken.

Where plenty of viable urediniospores are available and only one culture of a species is under greenhouse investigation, dusting with spores has been found the most effective method of inoculating large numbers of plants in a manner similar to that recommended by Fromme (1913). The plants are first atomized and then heavily rusted plants are shaken over them, after which they are placed in a moist incubation chamber. By this method the urediniospores are well scattered and the exposed plant parts usually are fairly uniformly inoculated. Where this method can be used, it has the advantage that a large number of plants can be inoculated quickly.

Aeciospores. Similar methods are used with aeciospores. There are several modifications, however, which have been found very serviceable. As aeciospores are catenulate, the lower spores being immature when the upper are ripe, scraping the aecia off with a scalpel removes many immature spores. When aecia have been produced in the green-

house, the spores are collected by fastening paraffined paper loosely around the infected parts of the plants in such a way that there are several openings for ventilation. The ripe spores which fall in this loose paper bag are scraped off and applied with a scalpel to the plants under investigation. Where sufficient inoculum is collected, it is dusted by using the glass blower described by Durrell and Parker (1920). Oftentimes in the greenhouse the peridia of aecia do not open but project out as a long cylindric column from which no spores are shed. If some of the infected plant parts bearing such aecia are placed upon waxed paper in a moist chamber over night, the peridial cells will fall apart and the mass of spores can be scraped from the paper for inoculating.

Teliospores. In those rusts where the teliospores are deciduous, dusting can be employed very effectively, as, for example, in *Kunkelia nitens*. However, in most species of the genus Puccinia, the teliospores are not deciduous and therefore must either be scraped off and applied with a scalpel or the plant parts bearing the teliospores laid on or around the plants to be inoculated in such a way that the basidiospores will reach the parts to be infected. Where sufficient material is available, the latter method probably is the better, as Melhus, Durrell, and Kirby (1920) point out that the teliospores of *Puccinia graminis* germinate better if not detached from the straw.

6. Condition of Plant Inoculated. In general, the plants to be inoculated should be in the best of growing conditions. It is a mistaken idea that weaker plants are more subject to rust. Plants which are in a weak and stunted condition, poorly developed from any cause do not readily infect or if infection takes place the rust does not develop well, the uredinia are fewer and smaller and often paler in color than when the host is developing vigorously. This also is true for parts of the same plant. Usually the young rapidly-developing plant parts are most readily and vigorously infected, the older, especially the senescent leaves and stems, showing much less infection. Not only is this true in case of the development of uredinia, but especially in the case of aecia.

The aecia of *Puccinia Clematidis* developing on the young, rapidly-growing stem of *Clematis virginiana* often produce marked hypertrophies and galls with the production of a large number of pycnia and aecia. Infection on very old leaves of the same plant usually produces only a few pycnia or possibly also a few aecia. On the other hand, telia usually develop when metabolism and growth are slowed up as in the case of ripening grain, under poor conditions of light and growth during midwinter in the greenhouse, or on old senescent leaves. However, the species of rusts vary considerably in this regard. Thus while *Puccinia montanensis* upon seedling grasses in the greenhouse in midwinter goes to telia so readily that it is sometimes difficult to keep it in culture, *Puccinia triticina* upon wheat seedlings has never been seen by the writer to produce telia under such conditions even on old dying leaves, but does produce some telia on old leaves when the wheat plants approach maturity.

7. Inoculation Chambers. Any sort of an enclosure which will permit the maintaining of a saturated humidity and a temperature optimum for the rust under investigation, will do for an inoculation chamber. When seedlings are to be inoculated sufficient light should be admitted to prevent excessive etiolation during the inoculation period. Unless provision for cooling the chamber is made, direct sunlight is to be avoided on account of the resulting high temperatures. Belljars have been quite generally used and are very satisfactory where the number of plants being inoculated is small. In this laboratory these are placed on a layer of wet sphagnum under the greenhouse bench where they

Fig. 2. Plant Covers which may be used either for inoculation chambers or for carrying of rust cultures.

receive diffused light. They have the disadvantage, however, of being easily broken and costly to replace.

As a substitute for belljars a modification of a plant cover (fig. 2) such as is used to shelter early planted cucumbers or melons has been found very satisfactory. These plant covers, as usually constructed, are too low for plants in pots. As a consequence it is necessary to have them made to order. Two sizes are constructed, one 21 inches high for 9-inch pots, and the other 14 inches high for 3- or 4-inch pots. The accompanying illustration (fig. 2) shows the general character of these plant covers. They are of cypress, except for two panes of glass which serve for the roof, and in consequence are very durable. If the glass is broken it usually can be replaced by cutting down broken greenhouse panes. These plant covers are used not only for inoculation chambers,

but have been found very useful for separating the various cultures of *Puccinia triticina* and other species in the study of specialized strains. As the panes of glass slide up and down in a groove, plants can be removed without lifting the cover and also various degrees of ventilation can be employed.

For still larger number of plants, galvanized-iron tanks, similar to those described by Parker (1918), Melchers and Parker (1922) and other investigators, are used. These are covered with lids in which panes of glass are inset, allowing entrance of light. Wet sphagnum in the bottom of the tank aids in keeping up the humidity. These tanks are kept under the greenhouse bench. The floor being of cement, they are easily pulled out to open and easily push back out of the way when closed.

One of the principal difficulties of successful culture in late spring, summer, and early fall is the high temperature of the greenhouse. By installing a system of spray nozzles beneath the greenhouse bench, the tanks, belljars and plant covers are cooled by a fine spray of water. By this means inoculation has been successfully carried out during the hot weather. When this system is used the tank covers are removed about twice a day for a few minutes and the plants are thoroughly moistened by leaving them exposed to the atomized spray. Thus the plants are aerated and covered with a fine dew, and the humidity of the chamber is renewed all in one operation. Belljars and plant covers are sprayed by means of a De Vilbiss atomizer. Inoculation chambers of the icelessrefrigerator type, described by Hunt (1919) also have been used in greenhouses where no spray system was available, cooling being obtained by evaporation from the wet muslin cover of the chamber. Melhus, Dietz and Willey (1922) also have described a series of muslin compartments in which their cultures are both kept and inoculated and which are cooled by a fine spray of water.

Where only one culture of a rust is being used in a greenhouse and the number of plants being inoculated is very large, as in the F_2 generation of a hybrid, the plants are dusted as described above and, after atomizing, a moist chamber is created by covering the pots of plants in place on the bench with heavy muslin. This is kept from resting on the plants by stakes placed at intervals in the bed. The muslin is kept wet by spraying as often as necessary during the day. This in reality is a very flexible moist chamber. It is especially useful where the plants to be inoculated are grown in soil on a greenhouse bench. In this way, thousands of seedlings of corn have been inoculated, notes taken, further selections of corn planted, inoculated, etc., all within a comparatively short time and with much less labor than if planted in pots and inoculated by hand.

8. **General Treatment of Cultures.** Inoculated plants usually are left in the moist chambers for about 48 hours. It is not advisable, when removing, to place them on the greenhouse bench in direct sunlight while tender from confinement in the moist chambers as the plants are likely to scald. It, therefore, is best to remove them in the late afternoon.

The incubation period of the rusts varies somewhat with the spe-

cies. In the case of *Puccinia triticina*, uredinia appear in 6-10 days after inoculation, development being most rapid in warm, sunny weather, and slowest in cool, cloudy weather. In the case of leaf rusts of wheat, rye, and barley the heavily infected leaves of seedlings die in about two weeks after the uredinia appear, and the plants thus become free of the rust unless reinoculated. If the leaves have to support only a small quantity of rust, infection may persist for some time, new uredinia being produced toward the border of the mycelium until there are two or even three concentric circles of uredinia around the uredinium first produced. As these rusts usually are carried on seedlings upon which it is desirable to produce as much infection as possible, it is necessary to transfer cultures about once every three or four weeks.

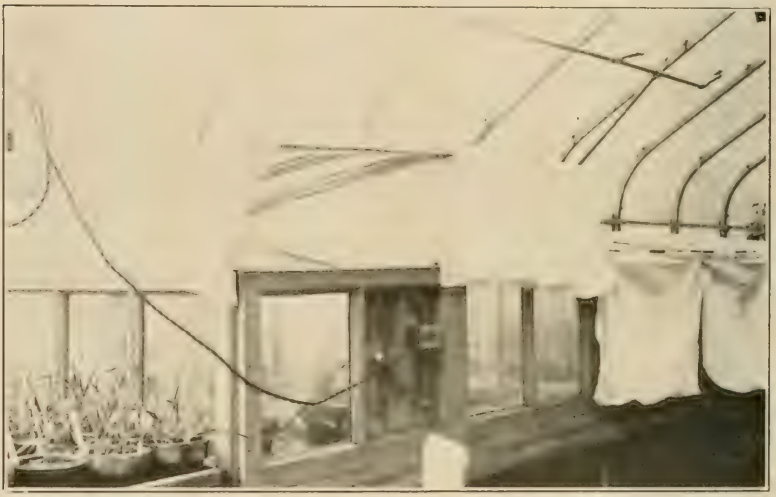

Fig. 3. Series of Wardian chambers for separation of rust cultures, showing right-hand two with sash down as used with spray and left-hand two with sash up and curtained off with muslin.

In the case of the rust of snapdragon, *Puccinia Antirrhini*, where the infected stems may not die for some time, the rust may continue to sporulate for two or three months, until the infected parts are killed. Corn rust, *Puccinia Sorghi*, maintains itself in the greenhouse as the funnel of unrolling young leaves makes an ideal moist chamber for spore germination. Whenever plants or plant parts overlap so that water persists on the lower leaves and a high humidity exists, the rusts will continue to reinoculate, provided temperatures are favorable for spore germination. Where comparative studies of different cultures are being made it usually is more desirable to limit the inoculation only to certain plants and therefore by proper spacing and care in watering, the rusts are prevented from reinoculating.

9. Comparative Study of Cultures. Where more than one culture of the same species of rust are being studied in order to determine if specialized races or strains exist and their behavior upon different spe-

cies or varieties of plants, it is very important that precautions be taken to prevent contamination of the cultures. Plants upon which these cultures are to be sown are grown in a greenhouse or compartment where the rust under investigation is not present. If the rust is very prevalent out of doors, as is the case with *Puccinia triticina* in the summer, it is necessary to grow such plants under very confined conditions, such as in a Wardian case (fig. 3), in order to protect them from wind-blown spores from without.

It would be highly desirable in such studies if methods as refined as those used in bacteriology could be employed. However, no nutrient medium has been devised upon which a rust can be grown. It is necessary to grow it on its living host and under the conditions which are favorable for the growth of such a host. Usually the confined conditions necessary to be absolutely sure there is no chance for contamination are not favorable for the best development of the host. In consequence, various expedients have to be employed. As the rusts primarily are wind-borne diseases, it is essential that direct air currents be avoided.

For this purpose, the partitions on the greenhouse bench made of a double thickness of muslin, and the cages of similar material used by Stakman, Piemeisel, and Levine (1918) have been found good. However, for *Puccinia triticina* the plant covers (fig. 2) described above have been found better, there being less chance of contamination. Where larger numbers of plants are being inoculated than these plant covers will hold, Wardian chambers (fig. 3) are used. These are made entirely of glass, the top being on the order of a hotbed sash so that a spray of water can be run on the chambers in the summer in order to lower the temperature. During the winter the sash usually is raised, the individual compartments being curtained off with muslin.

In the study of *Puccinia triticina* for the presence of specialized strains, some method was sought which would permit the growing of a fairly large number of single-spore cultures of the rust organism within a small space. The plan finally adopted was to sow wheat in four-inch pots filled with soil to the top. A lantern globe, covered over the top with a thin layer of cotton held in place with cheesecloth, was then pressed down into the soil as deeply as possible (fig. 4, D). The wheat coming up within this lantern globe is protected from wind-blown spores. Cultures of rust in such lantern globes can be carried from place to place without distributing spores or contaminating the cultures themselves.

During the winter months such leaf-rust cultures are maintained in good condition and transfers are made about every three or four weeks. During the summer, however, the high humidity and temperatures in such lantern globes are very favorable for the development of other fungi, especially Helminthosporium, which often kills the wheat and makes it difficult to carry the cultures through the summer. If only a few pots of seedlings are to be inoculated the spores developed in these lantern globes are sufficient. Where it is desirable to inoculate a large number of varieties at one time, so as to have all under as nearly the same set of conditions as possible, it is necessary to multiply the culture. The rust spores are first sown on wheat under another lantern globe in order that a pure culture may always be available. The remain-

ing inoculum is sown on as many pots of wheat as possible in plant covers or Wardian chambers. From the infection obtained, the set of varieties is inoculated.

After inoculating, the plants are placed on the greenhouse bench, possibly beside a set inoculated with another culture. As the humidity of the greenhouse does not reach the saturation point, and the seedlings are not grown thickly enough to provide such a condition among them, no infection results from one culture to the other on the bench. After notes are taken, the plants are discarded. If further investigations are carried out, the rust inoculum is obtained again from the lantern globe.

10. Pure Lines of the Rust Fungus. In the course of the investigations of the leaf rust of wheat *Puccinia triticina*, it became evident

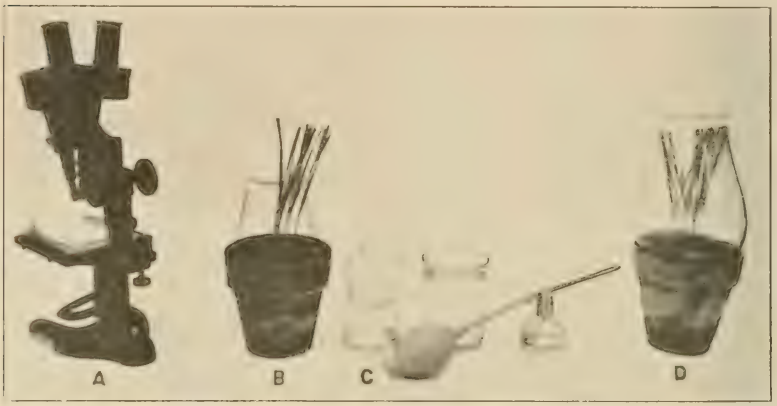

Fig. 4. Single spore cultures. Spore picked up from petri dish on binocular stage (A) by wet glass needles (C) and placed on wheat seedling (B). Culture covered with lantern globe (D).

that the rust organism as collected consisted of more than one strain. In order to be sure that the results obtained were characteristic of one strain of the organism and not due to a mixture of several strains, it became necessary to devise a method for obtaining a pure culture or pure line of the rust fungus. This can be done, with certainty only, by starting from a single spore. After a number of unsuccessful attempts to obtain such cultures the following method was found to work very successfully.

Urediniospores of a collection of the rust are gently dusted into a petri dish (fig. 4). This dish is placed under the highest powers of a binocular and a single urediniospore located, considerably separated from others. This is picked up by touching it with a wet glass rod drawn out to a fine point. By means of this glass needle, the spore is transferred to the moistened blade of a wheat seedling. Usually ten such plants, which have been grown under a lantern globe as mentioned above, are so inoculated. The culture is observed daily and as soon as the first

sign of a uredinium shows, all other plants are removed leaving the one plant with the one uredinium under the lantern globe. From this the culture is multiplied.

Another method, more easily used, consists in lightly dusting some spores on a pot of plants grown under a lantern globe. When uredinia first show, but before they have broken the epidermis, a plant is selected showing only one uredinium, all the rest being eliminated. If no such plant is found, but a plant is found having only one uredinium on a leaf, all the leaves but that one are cut off. By such a method one is not quite so certain of having a pure line as in the former, but in many cases it is practically as good.

11. Cultures of Rust Free from Other Fungi. In the usual culture work with rusts it is not necessary to exclude other fungi, especially saprophytes, yet if investigations looking toward the growing of these parasites on artificial media are undertaken, the rusts must be free from saprophytic fungi which otherwise will rapidly overgrow the cultures. The writer (1917) has elsewhere described such a method.

To recapitulate briefly, urediniospores of *Puccinia Sorghi* are sown on the upper side of leaves of corn plants grown in large sterile test tubes, from seed disinfected with corrosive sublimate. The first uredinia occur on the lower side of the leaves, and spores from these are sown on similar test-tube cultures of corn plants. Thus the rust might be said to have been strained through the corn leaf. Another method is to float small pieces of leaves from sterile corn plants on sterile sugar solution in small capsules. These pieces of leaves will take up the sugar solution and live for a considerable period. Spores taken from a freshly opened uredinium are used to inoculate the pieces of leaves in a number of these capsules. Spores from uredinia developed in those capsules which do not show saprophytic fungi are then used to inoculate a further series.

12. Recording Data. When only a few individuals of a small number of species or varieties are being studied, it is relatively easy to record in detail the symptoms produced when infected with rust. If an attempt is made to describe in detail all the symptoms shown by a large number of varieties, the time necessary for such notes becomes a serious limiting factor. To meet this difficulty a system of symbols has been in use in this laboratory, thus reducing the time necessary for note taking. These symbols indicate the terms applicable to the symptoms. They are as follows:

i = immune, no signs of infection.
f = flecks.
k = killed or necrotic areas.
M = mottled or chlorotic areas.
s = susceptible, no signs of resistance.
c = uredinia in concentric circles.
g = green islands of tissue surrounded by chlorotic.

The size of the uredinia is denoted as follows:

m = minute.

m = moderate in size.
$\overline{l}$ = large.
l = very large.

In resistant varieties where flecks, necrotic or chlorotic areas are produced, uredinia may or may not develop. This is denoted by the numeral, sub 1, following the symbol. When both areas with and without uredinia are found, the relative prevalence is denoted by writing the more numerous first, ex., ff_1 denotes flecks without uredinia more numerous than those with uredinia.

The susceptibility as illustrated in Figure 5, A would be recorded thus, s_1lc; B as s_1l; C as M_1l; D as s_1lk_1m; E as $s_1\bar{l}g$; F as k_1l; G as k_1km; H as $k\bar{k}_1m$; I as f.

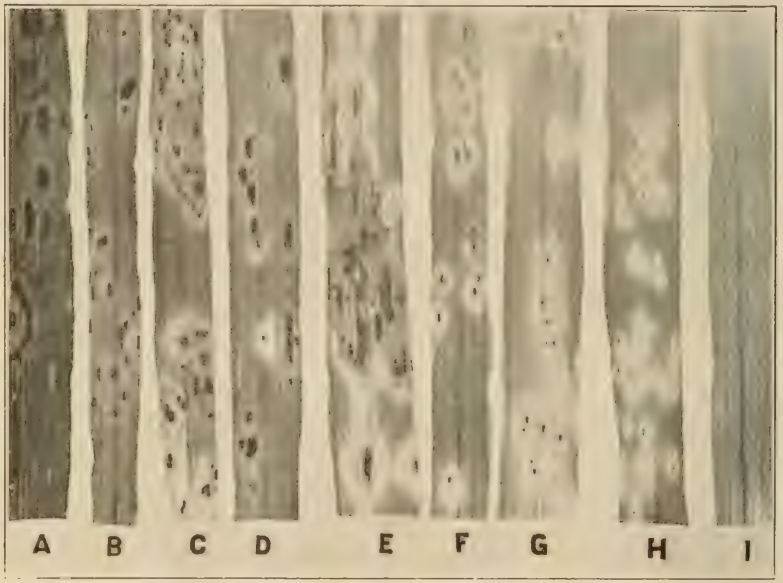

Fig. 5. Types of susceptibility shown by rye to leafrust, *Puccinia dispersa.*

Such a system can be arranged to meet the needs of the individual investigator. It should be emphasized that this is in no way a system of classification of susceptibility. It is a rapid method for the recording of symptoms from which the individual plant or the variety can later be placed in its proper class of susceptibility when enough types have been studied upon which to base such a classification.

The relative quantity of uredinia produced has been denoted in our notes by a corresponding segment of a circle surrounding the + mark denoting infection. This, however, should be replaced by some more suitable symbol. The number of plants infected out of the number inoculated is denoted by a fraction, the denominator giving the number inoculated and the numerator those showing infection, a method used by a number of investigators.

While detailed notes are necessary when an investigation is in progress, they would only be confusing in a publication of results. At this stage, however, the various types of susceptibility can be placed in a relatively few classes with some degree of accuracy. Vavilow (1913) following Eriksson has employed a classification based largely on the amount of uredinia developed on grain in the field. Stakman and Levine (1922) and a number of other investigators have used a similar system for their greenhouse investigations of *Puccinia graminis*, symptoms as well as quantity of uredinia being used as criteria. Mains and Leighty (1923) have used a similar classification for *Puccinia dispersa*. This may be arranged as follows for the leafrusts of wheat and rye:

0. No uredinia formed; hypersensitive areas sometimes present and definite, sometimes faint or absent. Fig. 5, I.

1. Uredinia few, minute, in the center of definite hypersensitive areas; few to many hypersensitive areas without uredinia. Fig. 5, H, G.

2. Uredinia fairly abundant, moderate in size but always surrounded by hypersensitive areas, hypersensitive areas seldom without uredinia. Fig. 5, F.

3. Uredinia abundant, moderate in size, without hypersensitive areas but in some cases surrounded by slightly chlorotic tissue. Fig. 5, C, B.

4. Uredinia abundant, very large, hypersensitiveness absent but uredinia occasionally in green islands. Fig. 5, D.

Where time is available, perhaps the best method of taking notes is to make herbarium specimens, especially where there is likely to be need of critical comparison later on. If infected leaves are dried quickly under moderate pressure, they will lose very little in color or other characters and will serve for several years at least as good material for reference. The plant press described by Jackson (1921) has been found especially good for this purpose, as the drying is very rapid, 12 hours usually being sufficient.

Photographs also are very important records, especially when publishing results. Many of the rusts are very difficult to photograph. This is especially true in the case of *Puccinia triticina*, where the uredinia are orange and the leaf is green in color. By the use of Wratten & Wainwright panchromatic plates and the B (green) Wratten M filter and enlarging two or three times, the uredinia photograph very well. Where a number of different types of susceptibility are to be photographed together, filters usually cut down the contrast on some of the types. It has been found that photographing by both reflected and transmitted light shows practically all the characters well defined, the uredinia appearing darker on account of transmitting less light than the leaf and the chlorotic areas, necrotic areas, and flecks appear lighter because they transmit more light.

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THE RECLAMATION OF SOIL BY VEGETATION.

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An exceptional opportunity afforded itself to make a study of the reclamation of soil by vegetation on a small scale, as will be set forth in this paper. In most cases of this kind the original conditions either are not known or one is so situated that he is unable to follow the progress of the revegetation of a given area. However, some cases are on record where the observer is not hampered by the above mentioned adverse conditions.

An extensive and admirable study of revegetation has been made by R. F. Griggs[1], who investigated the encroachment of plant life on the materials thrown out by volcanoes. Instances of this and other kinds of revegetation are also mentioned by Schimper[2]. That seeds of plants may be carried long distances by both air and water is well known. The proper elucidation, however, of many of the conditions involved in such dissemination has been especially well studied and reported by Schimper who observed that seeds may be carried long distances not only in the above ways, but also may they withstand adverse conditions during such carriage.

Treub[3] has also proved that spores and seeds can be carried long distances, at least 20 nautical miles, for he found the spores of 11 ferns and the seeds of two species of Compositae that distance inland on Krakatoa. Wallace[4] mentions instances of seed distribution and revegetation. Numerous instances could be recounted illustrating the capability of plants to obtain a new locality and grow and finally take possession of a given area.

That many plants will gain a foot-hold and grow in unfavorable conditions is in some instances well known. One such case the writer observed on the slopes of Mount Vesuvius, when a few years after an eruption, certain small trees and other plant life were growing on and among the cooled lava and ashes, on a surprisingly unsuitable surface. These plant forms were, of course, carried almost entirely by the agency of the wind and some of them for considerable distances. The vegetation here decreased rapidly from the base of Vesuvius upward until finally conditions were such that no plant growth was possible.

But one does not always find it necessary to study such a problem at a distance or over a large area in order to see the same factors at work, even if on an infinitesimally smaller scale. One of the difficulties is to find an area where complete plant denudation has been effected. The re-establishment of the plant forms in a very small area, as in large ones, can be seen in most cases to be extremely irregular in its

[1] Griggs, R. F. The Valley of 10000 Smokes. National Geographic Magazine, Vol. 31, 1917, pp. 13-68, and literature there quoted.

[2] Schimper, A. F. W. Pflanzen Geographie auf Physiologischer Grundlage, 1898, pp. 33, 200, etc., and the literature quoted in this work.

[3] Treub, M., in Schimper's Pflanzen Geographie auf Physiologischer Grundlage, 1898, p. 200.

[4] Wallace, A. R. Island Life, 1892, p. 77.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

advance—only the hardiest ones being able to gain a foothold and survive. Even many of these will be seen to start to grow for a time and then die, since some of the conditions in the new territory are too adverse to allow them to continue growth. After a time other individuals survive the soil conditions and reach maturity, at first probably not producing quite as vigorous specimens as those growing on distant territory.

It is interesting to see how soon the various forms of plant life will gain and become thoroughly established in the new territory. Some forms begin to grow in a short time, others only after a considerable period of time and some are later crowded out by the stronger forms in the general struggle to survive.

One plant that could not be overcome by the other species in the area to be discussed was the common *Ipomoea purpurea*. This plant, although it had no support at first, was heavily crowded by stronger forms which appeared after it had grown to a considerable size. Despite this hindrance it grew rather vigorously and almost as large, on the average, as other specimens in the open and under favorable conditions. It was interesting to compare on the other hand, a number of small and somewhat delicate forms, such as *Lobelia spicata*, which were crowded out. Other rather small and delicate forms persisted and completed their growth before the stronger forms came on.

The piece of ground to be considered was an area of 200 square feet. It was composed of heavy and rather damp clay and before this experiment began, was covered by a dense growth, mostly of *Poa pratensis*. It slopes gently to the east but more strongly to the south except for an artificial swale about the center of the tract. The ground to the west and north of the area is rich soil and heavily overgrown with *Poa pratensis*. In the directions just mentioned the grass was kept closely cut and free of all weeds to a distance of 75 to 100 feet. The same is true of the east and south although here less space intervened.

After a time it was noticed that some patches of *Rumex acetosella* put in their appearance, the seed having been introduced, in all probability with hay which had been strewn rather densely over the ground some time before these observations. This troublesome weed requires the application of quick and drastic methods if it is to be eradicated. The surest and one of the best ways to destroy *Rumex acetosella* is by the use of common salt, as experiment has sometimes shown. It is often necessary by this method, to sacrifice the surrounding vegetation, but however much it may be desired to spare other plants in the direct vicinity, it is generally time and money saved in the end to use salt in abundance and to leave everything else out of the consideration but the destruction of the *Rumex acetosella*. This plant has a tendency to grow in patches, due to its underground habit, and therefore it lends itself somewhat more readily to the above mentioned treatment than if growing more scattered. The *Rumex acetosella* was present on the ground here under consideration and was given two heavy treatments with common salt. This completely and permanently destroyed every vestige of these plants. A light application of the salt is very likely not to kill

Rumex acetosella as it may not reach the root stocks which are at varying distances below the surface. The soil recovers from the effect of the salt in a comparatively short time or if plowed up and cultivated in the spring after being treated with salt in the fall, vegetation of the desired kind when planted will grow uninterruptedly.

Subsequently to the treatment with salt on the ground here referred to—this plot was spaded and some time later was covered with clay. This clay was removed from under a large building which had stood over it for 19 years. Tests made on this clay soil showed that it contained no seeds of plants that would grow. The clay was deposited in April on the ground above mentioned, in a few places two feet deep, but in most places much less. The greatest depth of two feet happened to be over the southeast portion toward which drainage was most active. The swale above mentioned was preserved so as to provide drainage to the southeast as the slope of the land in general required.

All plants having been killed by the salt treatment, the forms to be enumerated later, which after a time appeared on this area, were carried in by various agencies, especially the wind. Some put in their appearance early, others not until considerably later, and most of them when once started grew fairly well from the first. One thing that favored the new in-coming forms of plants in this area was the rather perfect retention of the moisture in this clay soil. In dryer parts of the season this was particularly noticeable, especially when a comparison was made with other plants of the same kind in the same vicinity growing on soil which was more quickly deprived of its water by more thorough drainage.

Other forms appearing in this area plainly showed that the conditions were unsuited to their welfare since their growth was abnormal. Some of the larger plants gained entrance through the agency of water or animals, as in the case of *Zea Mays*.

The drainage was in the direction of this area for more than 100 feet above it, a circumstance which caused a considerable amount of water to cross this area to the southeast during heavy rains, and to spread out over it in the lower parts. As usual, many of the plants whose seeds were light and carried by the wind did not grow close to the area, but were to be found some distance away.

Plants started about the center of the area in question, showing that they had not simply broken through the thinner new soil at the edges, even if the former plants had not previously been killed with the salt application above mentioned. The spading of the area had turned the old soil with its salted surface deeply under. The only opportunity for plants to again grow on this area was for those forms which are generally disseminated by the usual agencies to find their way to the surface of the new soil. An area near this which was treated heavily with salt the preceding season and later plowed under, raised the following season a heavy crop of *Zea Mays* and other plants.

Woods[5] mentions the fact that common salt is of value when applied

[5] Woods, Alfred F. The Relation of Nutrition to the Health of Plants. Yearbook of the Department of Agriculture, 1901, p. 165.

to certain soils. This fact has been familiar for many years. The further mention of the use of this substance by English farmers to the extent of "two to three hundredweight per acre" shows its value in the soils concerned. Storer[6] and others have made valuable contributions on this point.

The observations of this study were carried on for two summers on the area here in question. During the first summer the introduction of the forms that appeared was slower than during the second season. At first the plants that grew were few in number and kind. However, it was easy to see that this state of affairs changed rapidly as the first season advanced and new plants appeared more and more quickly.

This was increased during the second year to such an extent that at the expiration of the second season the whole area was densely covered with plant forms, for the most part grasses of several kinds. The grasses covered the area so completely that this tract of land was cut over three times before the close of the second year.

In the meantime the other forms, especially coarse and large weeds were, for the most part, removed as their period of anthesis closed, to prevent them from seeding, and also to record those that might disappear.

By the end of the first season 41 different forms had put in an appearance on this area and reached maturity at or about the usual time, as was determined by observing other plants of the same species in the same locality. This, however, was not always the case, since some of the same plants which were observed as controls near this area, grew under more favorable soil conditions. *Ulmus Americana* put in an appearance early. This was readily accounted for since some elm trees of considerable size stood to the south of the area and about 75 feet away so that the winged seeds were easily carried by the wind. This form grew vigorously and in some number, but not more so than on the soil immediately surrounding this area. One specimen of *Juglans nigra* was found which was evidently carried in through the agency of some animal. Also two specimens of *Carya ovata* appeared the second season. This, however, is easily accounted for by the presence of a large tree of this species a few feet away from this area, so that a falling nut was readily transferred to this tract of land from this short distance.

Of all the forms that appeared on this area in the time noted the representatives of the Gramineae were the most numerous. These and other forms that grew here showed that wind, as would of course be expected, was the most important disseminator of the plants recorded. Of the 120 forms that were recorded by the writer and that appeared in this area in the two years' observation almost 30 belonged to the Gramineae. Not only did this family contain the greatest number of forms, but also the greatest number of individuals. By the end of the second year practically no difference could be ascertained a short distance away between this area and one that had been seeded for grass for a much longer time.

[6] Storer, cited by Woods, Alfred F., in the Yearbook of the Department of Agriculture, 1901, p. 165.

Various families of plants were never represented by more than one species, as the Juncaceae by *Juncus tenuis* and the Liliaceae by *Asparagus officinalis,* and the Portulacaeae by *Portulaca oleracea.* Other families, on the other hand, were represented by several representatives, such as the Cruciferae, the Leguminosae, the Euphorbiaceae, whose representatives have grown especially well and numerously in the last summer of 1921, as well as the Solanaceae and others. *Oxybaphus nyctagineus* was brought by me from Harrodsburg, Indiana, more than 20 years ago and planted in my garden. Since then it has spread at times more or less, but in such soil never in large numbers. It showed, however, a tendency to spread. Early in the second year of these observations it traveled to this new area about 100 feet away.

Next to the Gramineae the Compositae had during the two years of observations the greatest number of species represented in this area. Some of the genera were represented by numerous individuals, as would be expected of the genus Taraxacum. The 120 different species that were found on this area during the two years of observation were represented among other species of plants in the same vicinity. Especially was this true of some vacant land to the south of the area here discussed. This vacant land had for two years been in part plowed and used for gardens, but in a very poor and unsuccessful fashion. This land was weedy before plowing, particularly with *Vernonia altissima* and *Ambrosia artemisiifolia.* Afterward this land was entirely neglected and thus soon became a veritable pest-house for weeds. As this tract lay just to the south across a road and about 70 feet away, it thus became a very important source of weed infection of the area I have discussed above.

Barring its dense covering of weeds one especially was very conspicuous and numerous, namely *Lactuca canadensis* while *Vernonia altissima* above mentioned was at this time represented by only a few individuals and even these were, due to crowding and shading, by no means as robust as when this land was an open meadow.

The plants given in the following list for the area above discussed are arranged for the most part according to the 7th Edition of Gray's New Manual of Botany.

Zea Mays, Setaria glauca, S. verticillata, Sorghum halepense, Digitaria filiformis, D. sanguinalis, Paspalum setaceum, Panicum Gattingeri, P. Capillare, P. virgatum, P. microcarpon, P. huachucae, Axonopus furcatus, Phalaris canariensis, Phleum pratense, Sporobolus uniflorus, Agrostis alba, Avena sativa, Danthonia spicata, Bromus secalinus, Cynodon Dactylon, Eragrostis capillaris, Briza media, Dactylis glomerata, Poa pratensis, Festuca ovina, Hordeum sativum, Triticum sativum, Secale cereale, Juncus tenuis, Sisyrinchium angustifolium, Asparagus officinalis, Juglans nigra, Carya ovata, Ulmus americana, Cannabis sativa, Rumex crispus, Polygonum Hydropiper, Fagopyrum esculentum, Chenopodium album, Amaranthus retroflexus, Celosia argentea, Phytolacca decandra, Oxybaphus nyctagineus, Anychia polygonoides, Stellaria media, Cerastium vicosium, Saponaria officinalis, Portulaca oleracea, Sassafras varifolium, Draba verna, Capsella bursa-pastoris, Raphanus Raphanistrum,

Brassica nigra, Sisymbrium officinale, Agrimonia parviflora, Rubus villosus, R. allegheniensis, Trifolium pratense, T. incarnatum, T. repens, Melilotus alba, Medicago sativa, M. lupulina, Oxalis Acetosella, Euphorbia maculata, E. marginata, E. humistrata, Acalpha virginica, Acer saccharinum, Vitis cordifolia, Sida spinosa, Malva rotundifolia, Viola pedata, Oenethera biennis, Erigenia bulbosa, Pastinaca sativa, Daucus Carota, Vinca minor, Apocynum cannabinum, Asclepias syriaca, Gonolobus laevis, Convolvulus sepium, Ipomoea Batatas, I. purpurea, Prunella vulgaris, Solanum nigrum, Lycium halimifolium, Datura Stramonium, Physalis subglabrata, Verbascum Blattaria, Linaria vulgaris, Conobia multifida, Verbascum Thapsus, Veronica officinalis, Plantago major, P. lanceolata, Galium Aparine, Sambucus canadensis, Cucurbita Pepo, Lobelia siphilitica, L. spicata, Vernonia altissima, Solidago canadensis, Aster Shortii, A. ericoides, Erigeron annuus, Xanthium canadense, Rudbeckia hirta, Helianthus annuus, Bidens frondosa, Achillea Millifolium, Anthemis Cotula, Chrysanthemum Leucanthemum, Arctium Lappa, Cirsium lanceolatum, Taraxacum officinale, Sonchus oleraceus Lactuca canadensis.

MIDSUMMER GROWTH.

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In the year 1893 the writer's father transplanted a two year old specimen of *Liriodendron tulipifera*. This tree was cut down on account of some street work the present year (1923). It had attained a height of 21 meters and a diameter of 33 cm., one dcm. above the ground, in the 30 years. When standing it presented a beautiful spectacle with its towering slender shaft-like trunk and admirably balanced top.

Within the recollection of the writer it has been defoliated on three occasions, twice in one year, and once during a later year. When it was felled the writer started an investigation to ascertain how distinctly the above mentioned defoliations had impressed their results in the formation of the annual rings. Accordingly a disc 2.5 cm. in length was cut from the trunk of the tree one dcm. above the ground and exactly at right angles to the trunk by means of a guide which the writer has invented. The accuracy of this simple arrangement may be judged by the performance, since with a one-man cross-cut saw a variation of only a few mm. was shown in the above mentioned diameter cut of 33 cm. We have therefore in such cases, where proper care is used, a very commendable approach in a large scale, comparatively speaking, to the accuracy of an ordinary mitre box.

The disc cut as above described was next passed over a "jointer" which decidedly helped the visibility of the annual rings. The distinctness of the rings was further enhanced by sand-papering one side of the disc with a sanding block which was adjustable by means of a pintle. This last operation brought out the annual rings with much greater distinctness. The treatment above outlined made it possible to study the annual rings minutely. The section showed distinctly the

32 annual rings for the total number of years of the tree's age, and these stood out with unusual clearness. In addition, however, during the two years of defoliation above referred to, three other rings were observable although somewhat less clearly. A reference to the Weather Report records gave the explanation of these narrower annual rings. When the tree was 15 years old there occurred after the leaves were formed frosts on two successive nights which were so severe as to cause defoliation. After this leaves were again formed but later in the same year were destroyed by insects, a thing which rarely occurs with *Liriodendron tulipifera*. These two defoliations caused the formation of two rings or midsummer growths in the tree in its fifteenth year, which were not so distinct as the usual annual rings. The formation of two rings in one season is exceptional, but it shows, as stated by Jost, that a relation exists between defoliation and annual ring formation. When the tree was 23 years old it was again defoliated early in the season by frost which caused an extra ring to form. This was less distinct than the annual rings. These same midsummer growth formations were visible in some maple trees that were in the same locality, but they were less distinct than those mentioned for Liriodendron.

Various and numerous theories have been advanced concerning annual ring formation but as yet the real causes are unknown. Mechanical explanations have failed but the teleological viewpoint deserves study. While some facts are known concerning annual ring formation in temperate zones extremely little is known concerning annual ring formation in tropical trees. The first case of growth rings on record in a monocot has recently been reported by Chamberlain[1] for *Agave ferox* which grows in South Africa. In view therefore of the production of the midsummer growths as recorded in this paper, controlled experiments, although they would be costly to perform, should be carried out in order to determine the physiological facts involved in this important question.

STUDIES ON POLLEN—IV.

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Since my third contribution to this subject I have investigated the germinal behavior of more than a score of different pollens not heretofore considered in this series of studies. The more one progresses in this line of investigation, as in many others, the more one finds to be done in the various interesting and important phases of the subject. It is also clear that in many respects corrections of previous work needs attention and re-investigation from different angles. Improvements in the methods of research in this subject are constantly required as the work has progressed. The petri dish method has practically supplanted the procedures usually employed. A temperature arrangement has been devised which has definitely advanced this field of investigation. Too little attention has been paid heretofore to conditions controlling pollen

[1] Chamberlain, C. J. Growth Rings in a Monocotyl. Bot. Gaz., 72, 293-304, 1921.

behavior in the plant concerned. Therefore a study of pollen behavior, as far as possible, has been made in the field in certain cases for the sake of comparison with the laboratory experimentation. It is expected to extend this phase of the work.

Since my third paper on this topic I have increased the number of plants to 561. In all cases thus far the pollen has been tested in the various solutions referred to in my last paper. As yet no specimen has been found which for number of germ tubes produced is as prolific as *Malva crispa* referred to in my previous paper[1]. Some of the pollen reported in this paper refused to germinate under any of the laboratory conditions that were provided while in other cases germination occurred under precisely the same arrangements. In this last study no case of more than one pollen tube from a single grain has been observed. *Primula obconica* showed luxurious germination in most cases and under ordinary conditions is a favorable specimen for investigation. This was notable in as much as below and immediately above 10 per cent of cane sugar active germination was observed, but at 10 per cent none occurred in the specimens studied. This corroborates the findings heretofore brought out in certain other cases mentioned during these studies and it deserves further attention. There arises here also certain questions concerning the difference in the amount of time required for the commencement of germination aside from the influence of membranal variation. This I have found to be very different in the various pollens studied and constitutes a considerable problem in itself.

PROTOPLASMIC STREAMING.

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The idea of this chemical study in *Rhizopus nigricans* was to ascertain the behavior of the plant when plasmolysed in different degrees and the response of the protoplasmic movements when in this condition. It is well known that some plants when plasmolysed by certain substances may remain living for only a short time while others will live for weeks in this condition[2]. It is the intention to carry out this study by using various representatives from the six groups of metals as well as certain organic substances such as sugar and glycerine.

In the first experiments a 20 per cent solution of cane sugar was used. In these experiments a rather sudden plasmolysis resulted, in the time it was maintained, in a slowing of the streaming from a speed of three mm. per minute to one-tenth mm. per minute. When the normal hydrostatic pressure was restored the normal velocity of protoplasmic streaming above mentioned in these specimens was finally restored. In the series of specimens experimented with in this way, however, three hours elapsed before the normal speed was regained. The question still remains as to whether or not a full cessation of streaming could be

[1] Andrews, F. M. Studies on pollen—III. Proc. Ind. Acad. Sci., 1920, p. 155-156.

[2] Pfeffer, W. Pflanzenphysiologie 2te Aug. 1904, Bd. II, p. 330.

produced in a very short time; the length of time maintainable and the various conditions surrounding complete recovery without plasmolysis being produced. These remarks apply not only to very young but also to older specimens where streaming is observable. The sudden transfer from solutions of different concentrations below the plasmolytic strength is also in need of study. In one other set of experiments sudden plasmolysis was produced by a 40 per cent solution of cane sugar and in 15 seconds streaming ceased. In this case the protoplasm was plasmolysed into several parts. However, at the expiration of 21 hours the filaments all presented the normal appearance of the controls and were streaming actively but somewhat less rapidly than at first. In certain filaments of Rhizopus a comparative study of hyptogen membranes constitutes a topic of special interest.

Experiments with glycerine of 25 per cent, as expected, allowed no growth. In 12½ per cent glycerine seven spores in each 100 germinated. In 6 per cent 30 spores in 100 grew and in 3 per cent glycerine 82 in each 100 germinated and grew well.

Potassium nitrate having a strength of 2 per cent permitted a germination of 37 spores for each 100. Above this strength growth and streaming soon ceased. Above isosmotic valuations growth and streaming were feeble or ceased altogether.[3] The specimens plasmolysed by potassium nitrate lived a much shorter time than those plasmolysed by cane sugar.

[3] Eschenhagen. Einfluss von Lösungen verscheidener Concentration Auf Schimmelpilze, 1889, p. 55.

NITRATE STUDIES ON PURDUE ROTATION FIELD No. 6.

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Nitrate formation in the soil, although primarily a chemical transformation of protein nitrogen to nitrate nitrogen, is occasioned by the activities of certain groups of micro-organisms in the soil. Since the transformation is so dependent on the life processes of these organisms it is subject to the factors which ordinarily control living matter as well as those which regulate simple chemical phenomena. The following factors seem, from a study of the literature, to be most important:

Kind of soil, organic matter content of the soil, soil reaction, temperature, moisture, aeration, presence of suitable organisms, and the kind of crop grown. It was the latter point, the effect of the kind of crop and cropping system, that has been considered primarily in this study, although the other factors have been taken into consideration to a certain extent.

The plots on which this study was made, Purdue Rotation Field No. 6, were admirably adapted to the work, as they have been cropped and fertilized under a definite system since 1889, giving time enough for the soil conditions to have reached a constant in so far as these factors are concerned.

The work reported here is a continuation of work started in 1920 and first reported in the 1921 Proceedings of the Indiana Academy.[1] Inasmuch as this is purely a continuation of the work reported in the above paper and the technic used in the work is the same as that previously employed, with one exception, reference will be made to that paper for a résumé of the literature and a discussion of the technic employed.

In any study of nitrate formation, the data secured from a one year study of the problem are subject to considerable error as climatic and cultural conditions influence the process so markedly. In continuing the study over a series of years using the same plots, it is hoped to minimize the inconsistencies due to factors which vary from year to year and more closely narrow the problem down to a study of the one factor of crop influence on nitrification.

Tests were made every two weeks throughout the growing season in this work, instead of every month throughout the year as in the work previously reported. From past experience it seems that this is a more accurate measure of the factors concerned.

Effect of Various Crops on Nitrifying Power of Soil.

The following set of tables shows the moisture content, and nitrates in parts per million for the various rotations. The nitrates in all cases

[1] Baldwin, I. L., Coble, U. L., and J. W. Chamberlain. Crop rotation as affecting nitrate production. Proc. Ind. Acad. Sci., 1921 (1922), pp. 283-293.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

were calculated on a dry basis of the soil. The incubated samples were calculated on a basis of 21.5 per cent of moisture as that was found to be optimum, and it was endeavored to incubate them under as nearly optimum moisture conditions as possible. The incubated samples without ammonium sulphate added are shown in these tables as I; those with ammonium sulphate as II.

TABLE I.—Series 1 East

DATE	Plot 1 Wheat (Clover)				Plot 2 Corn			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated	
			I	II			I	II
April 21	28.50	5.37	14.50	17.04	29.01	4.06	8.04	17.28
May 6	24.81	3.46	9.32	18.28	24.73	2.98	8.64	22.46
May 20	21.80	1.64	8.30	22.64	23.15	3.76	16.21	32.14
June 3	15.36	2.26	13.06	21.20	19.27	6.18	28.60	33.09
June 17	13.43	6.22	19.15	25.62	19.13	12.25	32.44	42.81
July 1	13.48	9.61	22.81	28.67	18.64	18.64	39.82	48.25
July 15	16.08	11.06	23.20	27.84	20.19	20.77	40.24	46.60
July 29	13.12	10.48	19.91	31.68	18.92	22.04	42.60	48.00
Aug. 12	11.93	8.54	17.43	26.91	16.57	16.56	39.27	40.76
Aug. 26	17.94	12.26	19.84	24.62	21.06	18.63	39.88	43.66
Sept. 9	14.65	7.95	17.60	22.98	17.82	14.80	32.29	35.75
Sept. 23	12.11	6.43	16.19	19.89	14.68	18.92	21.84	33.78
Oct. 14	24.43	1.70	12.04	18.46	23.76	11.52	18.60	33.09
Oct. 30	22.76	1.66	10.23	15.61	22.20	8.21	16.74	27.36
Average	17.88	6.19	15.97	22.96	20.65	12.81	27.52	36.07

DISCUSSION OF SERIES 1 EAST (CORN AND WHEAT).

(Table I.)

The fresh nitrate content of the wheat plot was low during May and the early part of June at which time the crop was draining heavily on nitrates. By July 10 it had reached nearly 10 parts per million and remained at this point with minor fluctuations until about September 1, when it gradually went down because of dry, cool weather and the withdrawal by the clover crop. The incubated samples were consistently higher than the fresh. Those with ammonium sulphate averaged about 65 per cent higher than those without, which fact seems to indicate that suitable nitrogenous materials and not absence of sufficient organisms was the limiting factor.

The fresh nitrate curve of the corn plot is much the same as that of the wheat, but it is higher at all times except early in the season. The highest point of 22.04 parts per million was reached on July 29. Rains during the season, when not hard enough to leach out the nitrates, caused a rise in the fresh nitrate content. The incubated samples were much higher in nitrates than the fresh samples during the whole season. During the middle of the summer the addition of ammonium sulphate had little effect, which fact tends to show that the efficiency of the nitrifying organisms in the soil at that time was greater than at other seasons of the year. This instance seems to confirm the general theory

that it is in the early spring that crops need applications of quickly available nitrogenous fertilizers.

TABLE II.—Series 1 West

DATE	Plot 3 Clover and Timothy				Plot 4 Corn			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated	
			I	II			I	II
April 21	27.70	3.54	14.62	18.26	27.99	6.57	13.96	19.30
May 6	26.71	3.49	7.60	23.90	24.48	3.76	11.52	20.62
May 20	25.09	2.56	10.08	19.40	24.30	6.76	23.48	24.61
June 3	16.08	1.86	10.90	20.82	19.41	8.32	24.81	33.18
June 17	12.32	3.68	13.12	24.52	19.01	14.06	34.21	43.80
July 1	11.23	4.12	16.71	26.40	18.90	16.45	36.21	45.01
July 15	13.87	5.58	17.05	31.96	19.23	26.09	41.19	41.86
July 29	11.43	6.08	19.25	29.61	17.64	18.64	38.40	44.71
Aug. 12	10.31	7.02	22.03	26.30	16.38	19.21	38.99	45.87
Aug. 26	16.96	5.98	20.41	25.86	20.53	24.33	39.45	43.72
Sept. 9	13.19	5.74	16.36	24.91	15.93	21.40	38.50	39.74
Sept. 23	11.36	5.42	16.77	18.40	13.51	19.90	30.61	38.20
Oct. 14	24.96	5.01	11.43	12.62	22.61	6.82	27.92	34.33
Oct. 30	22.89	1.65	9.69	11.45	21.43	5.43	20.57	25.06
Average	17.44	4.41	14.72	22.46	20.10	14.12	29.99	35.72

TABLE II.—Series 1 West—Continued

DATE	Plot 5 Oats				Plot 6 Wheat			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated	
			I	II			I	II
April 21	25.75	5.03	11.48	16.28	27.68	2.65	14.70	16.44
May 6	23.76	1.98	13.06	20.09	25.08	1.71	8.21	9.02
May 20	21.58	2.45	12.73	22.50	24.79	1.57	8.96	16.34
June 3	16.21	1.94	13.92	20.30	15.52	1.98	12.80	17.06
June 17	13.03	3.26	14.37	26.04	13.21	7.57	17.85	24.23
July 1	11.11	4.06	14.63	27.05	12.70	7.30	18.72	22.33
July 15	13.81	6.74	16.20	29.03	15.97	9.36	18.99	25.07
July 29	11.47	6.20	16.92	28.62	12.84	10.01	17.83	26.90
Aug. 12	10.13	6.42	14.49	25.87	11.27	9.87	21.02	26.45
Aug. 26	17.59	4.06	14.52	23.90	18.00	11.78	20.68	25.54
Sept. 9	15.76	4.22	12.83	23.06	14.96	7.81	19.98	23.19
Sept. 23	14.41	4.78	11.95	14.44	12.37	7.63	19.06	23.38
Oct. 14	23.45	2.67	9.06	13.97	24.33	2.54	15.27	19.16
Oct. 30	22.31	3.38	8.60	10.21	22.74	3.70	13.63	15.09
Average	17.17	4.09	13.20	21.53	17.96	6.11	16.26	20.73

DISCUSSION OF SERIES 1 WEST (CORN, OATS, WHEAT, CLOVER AND TIMOTHY). (TABLE II).

The fresh nitrate content of the clover and timothy plot (about 9/10 timothy and 1/10 clover) was low throughout the season. It was exceedingly low in May and June at which times the crop was drawing heavily on the nitrates. The highest point of 6.08 parts per million was reached July 15. The incubated samples showed fairly high throughout the season. The addition of ammonium sulphate caused a great

increase, which fact tends to show that lack of suitable organic matter was one of the limiting factors.

The corn plot showed a higher fresh nitrate content at all times than did any of the other three plots. The highest point of 26.09 parts per million was reached on July 15. This high point as well as the high point on August 26, can be partly explained by the rains preceding both dates. The two incubated sets showed relatively little difference, which fact tends to show that the organisms present were able at this time to easily change organic matter into nitrates.

The fresh nitrate content of the oat plot was low during the whole season, being the lowest during May and June when the crop was using the most. The incubated samples ran much like those of the clover and timothy plot, the addition of ammonium sulphate causing a substantial increase. None of the incubated samples, however, reached the high point reached by the corn plot.

The wheat plot was low in fresh nitrates in May and the beginning of June. The highest point, of nearly 12 parts per million, was reached on August 26 following the rain which fell a few days previously. Mention may be here made that probably one reason why most of the plots showed a fairly uniform nitrate content during the whole summer is that no hard rains were received which would tend to leach out the nitrates which were above that used by the crops. Therefore, the nitrates stayed fairly high during the whole summer until the rains of late September washed them out. Although very little nitrates were produced in the non-cultivated plots during the dry season, the samples still showed a fairly high content.

TABLE III.—Series 2 East

DATE	Plot 7 Wheat				Plot 8 Corn				Plot 9 Oats			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated			Fresh	Incubated	
			I	II			I	II			I	II
Apr. 21	28.42	2.68	12.08	17.16	27.93	2.66	13.98	16.78	27.35	10.57	12.24	13.96
May 6	25.16	2.56	6.92	20.90	25.23	3.85	17.64	24.56	24.76	6.38	10.68	22.89
May 20	23.30	2.50	9.54	26.39	25.21	6.85	22.87	35.40	23.00	4.98	22.55	20.19
June 3	15.15	1.43	12.60	23.89	19.31	7.20	26.86	34.72	16.93	2.76	13.64	21.54
June 17	14.04	8.73	13.95	28.83	18.94	10.47	27.61	36.20	13.42	3.08	11.72	24.67
July 1	12.87	12.41	17.88	30.43	18.48	25.19	33.53	42.26	12.36	4.88	13.65	28.50
July 15	16.70	14.62	19.07	31.70	21.07	26.12	29.56	39.81	16.03	6.04	10.95	29.86
July 29	12.09	10.86	22.10	32.08	19.09	21.09	22.81	36.51	12.61	7.02	13.80	33.14
Aug. 12	10.76	9.32	23.29	33.39	17.11	15.42	22.20	38.94	10.45	6.65	12.61	32.46
Aug. 26	17.20	7.85	22.44	30.50	21.93	17.81	25.49	37.63	17.97	5.21	13.43	30.42
Sept. 9	14.11	5.76	22.81	30.81	16.89	15.06	21.16	32.45	16.05	6.39	12.18	25.10
Sept. 23	12.61	6.06	17.66	26.62	14.68	14.43	21.23	30.14	15.59	6.93	10.83	19.64
Oct. 14	25.21	3.94	14.19	20.28	21.95	9.81	19.95	22.70	24.27	3.38	7.06	18.78
Oct. 30	23.07	4.08	13.08	16.85	21.18	6.23	17.54	19.67	22.32	3.94	5.16	12.75
Average	17.91	6.63	15.54	26.43	20.64	13.01	23.12	34.13	18.08	5.59	12.16	23.85

DISCUSSION OF SERIES 2 EAST (CORN, OATS, WHEAT). (TABLE III.)

The wheat plot was low in fresh nitrates during May, in the first part of June, and reached its highest point of 16 parts per million on

July 15. From then on until the last sample was taken it steadily went down, differing in this respect from the previous wheat plots discussed. The addition of ammonium sulphate to the incubated samples caused a large increase, more at the beginning of the period than toward the end. This instance again seems to show that it is in the beginning of the season that crops need applications of quickly available nitrogenous fertilizers.

The nitrate content of the fresh samples of the corn plot was also highest on July 15. The curve goes down with a few fluctuations until October 30, being similar in this respect to the wheat plot in this series. No explanation can be offered for this difference from the plots of the other series. The incubated samples with ammonium sulphate showed a much larger increase over those without ammonium sulphate than in the case of the previous corn plots. This condition may have been due to the fact that there is no clover and timothy crop in this rotation; and hence there was not as much available nitrogen present (in previous years the stand of clover was better than this past season).

For some reason, not apparent, the fresh nitrates of the oat plot were higher on April 21 than at any other time during the season, and this in view of the fact that there had been a period of almost incessant rain immediately preceding that time. During the rest of the season the fresh nitrates were low, being lowest during the period when the crop was drawing most heavily on them. The incubated samples with ammonium sulphate were on the average about 100 per cent higher than the samples without it. Therefore, it seems that an application of some nitrogenous fertilizer would be beneficial. An interesting point in connection with this plot is that after being plowed for wheat about August 26, the moisture content stayed up whereas the moisture content of the unplowed wheat plot went down rapidly.

TABLE IV.—Series 2 West

DATE	Plot 10 Cl. & Tim.				Plot 11 Corn				Plot 12 Wheat			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated			Fresh	Incubated	
			I	II			I	II			I	II
Apr. 21	29.62	3.18	13.84	20.16	27.79	6.24	13.30	14.86	27.22	5.71	10.75	13.04
May 6	26.37	2.16	10.42	25.75	27.27	6.59	20.08	23.26	24.50	2.01	9.28	25.60
May 20	26.02	3.46	22.69	29.74	25.15	6.84	27.92	29.96	23.91	2.52	21.16	27.88
June 3	16.71	2.42	14.06	23.28	20.96	12.41	29.62	27.90	15.03	1.48	17.76	28.52
June 17	12,72	4.36	18.59	29.73	19.37	16.64	39.84	40.09	13.78	7.64	18.73	27.49
July 1	11.61	4.63	19.20	32.34	19.71	17.29	43.73	48.69	12.76	7.69	19.26	33.05
July 15	16.40	8.94	22.46	36.30	22.11	25.45	41.53	44.89	16.53	14.02	22.57	38.40
July 29	11.96	9.12	21.55	32.64	19.49	21.17	42.32	42.49	13.01	13.16	21.95	40.21
Aug. 12	9.97	9.26	18.22	35.20	17.31	18.42	37.68	44.70	11.56	13.43	21.71	39.50
Aug. 26	16.41	7.47	21.08	33.60	21.34	24.26	37.98	40.22	17.18	10.81	19.82	35.66
Sept. 9	12.98	5.31	20.37	30.67	16.77	23.13	30.16	35.43	12.22	7.03	18.22	34.57
Sept. 23	11.01	4.76	15.30	21.24	13.89	24.09	30.40	35.12	10.87	6.84	16.74	30.19
Oct. 14	23.25	3.33	14.04	21.46	24.38	10.88	20.77	25.19	25.05	2.76	10.45	21.55
Oct. 30	22.09	4.62	9.61	17.46	22.41	8.90	17.44	23.39	23.46	2.89	8 82	13.69
Average	17.69	5.00	17.25	27.83	21.28	15.88	31.56	34.01	17.65	7.00	16.94	29.24

DISCUSSION OF SERIES 2 WEST (CORN, WHEAT, CLOVER AND TIMOTHY). (Table IV.)

The clover and timothy soil showed a low fresh nitrate content, being especially low in May and the early part of June. The highest point was reached immediately after the harvesting of the crop. In comparing the incubated samples, it can be seen that the addition of ammonium sulphate materially increased nitrification, which fact seems to show that there was a deficiency of easily available nitrogenous materials.

The corn plot reached its high point on July 15, and stayed rather uniformly high until October 1. The addition of ammonium sulphate to the incubated samples did not show much of an increase. This condition may have been due, no doubt, to the fact that clover sod had been plowed under, and there was, therefore, a fairly large supply of easily available nitrogen present. The ability of the nitrifying organisms to change organic matter into nitrates was also probably enhanced about this period.

The fresh nitrates of the wheat soil were low in May and early June, reached their highest points in July and early August, and then fell off gradually. The presence of the clover in the stubble probably caused the fresh nitrates to fall sooner than they otherwise would have done. The addition of ammonium sulphate caused a marked increase in the nitrification in the incubated samples, indicating a deficiency in easily available nitrogenous materials.

TABLE V.—Series 3 East

DATE	Plot 13 Wheat (Unlimed)				Plot 14 Wheat (Limed)			
	Moisture Per Cent	Nitrates—Parts per Million			Moisture Per Cent	Nitrates—Parts per Million		
		Fresh	Incubated			Fresh	Incubated	
			I	II			I	II
April 21	27.55	3.53	9.82	15.06	27.93	5.33	10.88	18.34
May 6	24.33	2.52	8.98	20.32	25.10	2.63	8.16	21.05
May 20	22.62	3.58	8.60	14.52	22.25	6.09	12.08	20.67
June 3	15.43	1.62	9.22	16.18	15.51	3.21	11.48	19.62
June 17	13.64	7.47	11.66	22.07	13.05	6.12	17.15	23.83
July 1	12.23	9.32	13.43	26.91	12.86	10.60	18.23	25.42
July 15	15.89	9.81	17.20	25.60	16.04	12.19	18.08	28.73
July 29	11.89	10.46	15.98	27.72	12.77	10.09	16.94	28.83
Aug. 12	10.49	9.84	15.86	28.14	11.03	10.62	16.08	29.36
Aug. 26	17.86	12.24	13.21	27.43	17.74	13.96	14.66	28.96
Sept. 9	16.47	19.20	16.43	27.62	16.26	16.36	14.47	25.18
Sept. 23	15.83	16.85	16.60	26.84	15.73	14.27	15.33	25.04
Oct. 14	23.15	5.31	11.27	20.80	24.04	7.03	11.85	20.77
Oct. 30	21.96	6.02	10.26	18.63	22.38	7.86	11.09	18.14
Average	17.81	8.41	12.61	22.70	18.05	9.03	14.03	23.13

DISCUSSION OF SERIES 3 EAST (CONTINUOUS WHEAT). (Table V.)

The two plots in this series have been in continuous wheat since 1889. Since 1911, plot 14 has received an application of lime every four years, while plot 13 has received nothing. The fresh nitrate content of both ran close during the whole season. The limed plot was slightly

ahead of the unlimed plot most of the time. Both plots showed a low nitrate content in May and early June. Both plots were plowed for wheat about August 20. The increase in conservation of moisture and aeration resulting from the plowing probably caused the great increase in nitrification in September. In both cases the incubated samples with ammonium sulphate showed a substantial increase in nitrification over the samples without it. This condition was probably caused by a deficiency of quickly available organic nitrogen, resulting from the continuous cropping. By comparing the two plots, it would seem that liming tends to increase nitrification.

TABLE VI.—SERIES 3 WEST

Date	Plot 15 Continuous Corn (Rye)			
	Moisture Per Cent	Nitrates—Parts per Million		
			Incubated	
			I	II
April 21	26.55	3.92	8.96	15.60
May 6	23.53	9.38	11.80	28.65
May 20	23.90	11.56	19.86	24.93
June 3	20.91	12.13	22.58	26.85
June 17	19.46	11.20	21.70	36.18
July 1	19.19	24.49	27.80	43.92
July 15	22.03	25.76	23.22	44.29
July 29	19.49	17.64	21.80	46.77
Aug. 12	17.61	15.23	21.96	43.44
Aug. 26	21.06	9.61	19.67	38.76
Sept. 9	17.96	7.48	15.26	32.49
Sept. 23	16.09	11.52	16.94	31.55
Oct. 14	24.76	9.24	16.38	26.87
Oct. 30	23.28	3.46	12.60	25.82
Average	21.12	12.33	20.61	33.22

Discussion of Series 3 West (Continuous Corn). (Table VI.)

This plot, like plots 13 and 14, has been continuously cropped. Rye has been sown in the corn in the autumn and plowed under in the spring. The moisture content was about optimum during May as a result of the heavy growth of rye that had been turned under which permitted the surface water to soak in more quickly, while the soil from the other corn plots was above optimum in moisture. The above explanation probably accounts for the fresh nitrate content being higher at that time than in the case of the other corn plots. The highest point

was reached on July 15. The incubated samples with ammonium sulphate showed much higher nitrification than those without, indicating a deficiency in available nitrogenous materials in the soil.

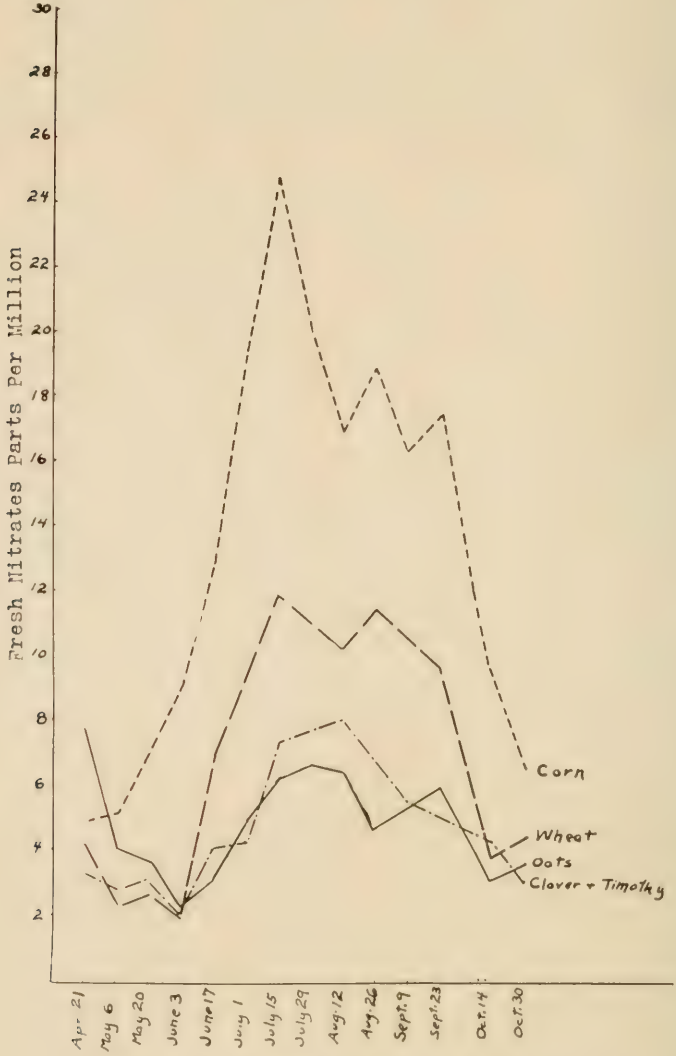


Fig. 1. Average fresh nitrates of the various crops.

COMPARISON OF THE AVERAGES OF THE VARIOUS CROPS.

The fresh nitrate content of the soils from all the plots in the same crop were averaged for each date of sampling. The accompanying graph shows these averages for the four crops.

By reference to figure 1 it will be noticed that the fresh nitrate content of the corn soil was highest of all soils throughout the season. The highest point of nearly 25 parts per million was reached on July 15, after which date the nitrate content dropped off until the end of

Fig. 2. Comparison of the effects of the various rotations on nitrification.

the season. The increases on August 26 and September 23 can be explained by virtue of the rain immediately preceding those dates.

The soil from the wheat plots was low in nitrates during May and early June, but went up materially during latter June and early July, reaching the highest point on July 15 as the corn soil did. The depression on August 12 was probably due to the extremely dry weather immediately preceding that date.

The oat soil was highest of all the soils on April 21, but went down in nitrate content during May and June. During July there was an increase, but compared with wheat and corn the nitrate content was low all season.

The timothy and clover plots showed a low nitrate content throughout the season, being very similar in this respect to the oat plots. The highest point of 8 parts per million was reached on August 12.

The curves on the graph of the clover and timothy and oat plots only represent the averages of two plots, while the ones for wheat and corn represent the average of six and five, respectively; hence the two former curves are probably not as reliable for those particular crops as are the ones of wheat and corn.

The following general conclusions can be drawn:

(1) Corn soil shows higher nitrifying power than do wheat, oat or clover and timothy soils.

(2) Wheat soil shows a higher nitrifying power than oat or clover and timothy soils.

(3) Clover and timothy and oats seem to have a depressing effect on nitrification processes in the soil.

TABLE VII.—AVERAGE NITRATE CONTENT

Series	Crop	Plot No.	Nitrates—Parts per Million		
			Fresh	Incubated 2 wks.	
				I	II
1E	Corn	2	12.81	27.52	36.07
1W	Corn	4	14.12	29.99	35.72
2E	Corn	8	13.01	23.12	34.13
2W	Corn	11	15.88	31.56	34.01
3W	Corn	15	12.33	20.61	33.22
1E	Wheat	1	6.19	15.97	22.96
1W	Wheat	6	6.11	16.26	20.73
2E	Wheat	7	6.33	15.54	26.43
2W	Wheat	12	7.00	16.94	29.24
3E	Wheat	13	8.41	12.61	22.70
3E	Wheat	14	9.03	14.03	23.13
1W	Oats	5	4.09	13.20	21.53
2E	Oats	9	5.59	12.16	23.85
1W	Cl. & Tim.	3	4.41	14.72	22.46
2W	Cl. & Tim.	10	5.00	17.25	27.83

Effect of Crop Rotation on Nitrifying Power of Soil.

Table VII gives the average nitrate content during the whole season for all the plots. The same crops are grouped together so that direct comparisons can be made.

The graphical comparison, figure 2, shows more clearly the comparison between the same crops, as well as the effect of the various rotations on the nitrifying power of the soil.

Because of the fact that the fresh nitrate content of a soil is only that part of the nitrate above that which is leached out and used by the crop, the nitrate content of incubated samples is more indicative of the effect of a crop or cropping system on the nitrifying power of the soil.

To illustrate this point it will be noticed that the average fresh nitrate contents of plots 13 and 14 (continuous wheat) are higher than any of the other wheat plots. Turning back to the previous tables, the fact can easily be seen that this high average was a result of the stimulus given to nitrification in late August and September following the plowing of these plots for wheat.

It was primarily for the purpose of determining the effect of the various crop rotations on the nitrifying power that the determinations of the nitrate content of incubated samples No. 1 (those without ammonium sulphate) were made. The purpose of the incubated samples with ammonium sulphate has already been implied in the previous discussions, i. e., to determine whether easily available nitrogenous materials were or were not a limiting factor in the nitrification processes in the various plots.

In table VII the averages for all three sets of samples are given, but only the averages for incubated samples I will be discussed for the reasons already given.

Plot II showed the highest average of all the corn plots with an average nitrate content of 31.56 parts per million; plot 12, wheat, showed the highest average of all the wheat plots with 16.94; and plot 10, clover and timothy, showed the highest nitrate content of the two clover and timothy plots with 17.25 parts per million. It would seem then that the corn, wheat and clover and timothy rotation was the most efficient in nitrifying power.

Plot 4, corn, was second in nitrate content to plot II with an average of 29.99 parts per million; plot 6, wheat, was second of all the wheat plots with 16.26 parts per million; and plot 5, oats, with 13.20 had the highest nitrifying power of the two oats plots. The above facts seem to indicate that the corn, oats, wheat and clover and timothy rotation had the second greatest effect on nitrification.

Plot 2, corn, with 27.52 parts nitrate per million, was third highest in nitrate content of the corn plots, and plot 1, wheat, was the third highest of the wheat plots with 15.97 parts nitrate per million.

Plot 8, corn, was fourth in average nitrate content with 23.12 among the corn plots; plot 7, wheat, was fourth among the wheat plots with 15.54; and plot 9, oats, was lowest of the two oats plots with 12.16 parts of nitrate per million.

Plots 13 and 14 (continuous wheat, unlimed and limed respectively) were lowest in average nitrate content of all the wheat plots.

Plot 15, continuous corn, was lowest of all the corn plots with only 18.61 parts of nitrates per million.

From the above facts the following conclusions can be drawn:

(1) It seems that the following rotations are effective in producing high nitrifying power of the soil, in the order named: (1) Corn, wheat, clover and timothy; (2) corn, oats, wheat, clover and timothy; (3) corn and wheat; and (4) corn, oats and wheat.

(2) Soil continuously cropped to either wheat or corn shows a lower nitrifying power than soil cropped to any of the above rotations.

(3) The present crop has more influence on nitrification than previous crops.

SOME SOIL AND WATER REACTIONS IN THE DUNES REGION OF PORTER COUNTY.

Marcus Ward Lyon, Jr., South Bend.

During a two weeks' stay, October 21 to November 4, 1923, at the dunes of Porter County, devoted mainly to collecting small mammals, I made a number of hydrogen ion concentration determinations of the soil and water in the regions opposite Tremont and Mineral Springs, stations of the Chicago, Lake Shore and South Bend Railway. My interest in making the determinations came through knowledge of the value of proper hydrogen ion concentration in bacteriologic work and its still greater importance in our own body fluids, such as blood where the normal range is within the narrow limits, PH 7.6 to PH 7.8, specific alkalinities of 3.98 to 6.31. (At PH 7.5 to PH 7.2, specific alkalinities of 3.16 to 1.58, the pathologic condition of acidosis ensues and if the lower figure is maintained for any length of time death results.) The existence of two botanically different wooded swamps or swamp-like areas, one opposite each of the railway stations mentioned suggested further interest in the question as a possible explanation of their differences.

The method of making the determinations was that devised by Wherry[1], and use was made of the simple apparatus placed on the market as a "soil indicator set" by the La Motte Chemical Company of Baltimore. I found it desirable to use more test-tubes than accompany the set. The results of each determination were reached by observing the color changes of at least three indicators rather than by basing them on the specific color changes of one.

The chief aim was to determine whether there were any average differences in the soil and water acidities of the two wooded swamps referred to rather than to determine the acidity of the soil of specific plants. The differences in acidity of these two swamps were so slight and almost inconsequential that I determined the acidity of other places in the dunes.

Each of the two wooded swamps seems about equally wet and shaded. The swamp opposite Tremont is slowly traversed by Dune Creek. The conspicuous plants found in it and not found in the Mineral Springs swamp, or at most but sparingly are: *Platanus occidentalis, Carpinus caroliniana, Asimina trifolia, Trillium grandiflorum, Trillium sessile, Arisaema triphyllum, Arisaema dracontium.*

The tamarack swamp opposite Mineral Springs station has practically no drainage although the water in it seems to seep eastward toward the west branch of Dune Creek. The conspicuous plants found in it and apparently not found in the Tremont swamp or at most but sparingly are *Larix laricina, Thuja occidentalis, Betula papyrifera,*

[1] Wherry, Edgar T., Determining soil acidity and alkalinity by indicators in the field; Journ. Wash. Acad. Sci., Vol. 10, pp. 217-223, 1920.

———, Soil acidity—its nature, measurement and relation to plant distribution; Ann. Rept. Smithsonian Inst., 1920, pp. 247-268, 1922.

Betula lutea, Toxicodendron vernix, Sambucus racemosa, Cornus canadensis, Coptis trifolia, Cypripedium candidum and *Cypripedium hirsutum*[2].

These two wooded swamps are about two and a half miles apart. Between them is an unwooded swamp or marsh, in places quite wet where the conspicuous plants are sedges growing in tussocks, *Spiraea tomentosa Rosa carolina*, and a few examples of *Habenaria ciliaris* and *Gentiana saponaria.*

Just north of the Mineral Springs swamp is an interdunal pond and meadow called Little Lake[3]. The striking plants of this wet meadow are *Rhynochospora macrostachya, Eriocaulon septangulare, Drosera intermedia, Rhexia virginica, Polygala cruciata* and *Utricularia vulgaris.*

Just south of the Mineral Springs tamarack swamp and continuous with it is a very wet quaking bog. The conspicuous plants in it are various rushes, *Parnassia caroliniana, Sarracenia purpurea, Oxycoccus macrocarpus, Gentiana detonsa, Gerardia purpurea, Lobelia kalmii* and *Decodon verticillata.*

It was impossible to determine soil and water acidities throughout the entire extent of all these areas, but a few characteristic portions of each were selected and acidities determined in them. In addition to these some determinations were made of the soil of the wooded dunes, of the fore-dune area, of the water of Lake Michigan, of an artesian well and of a pump well.

Acidities of these places are given in the following table expressed in terms of what Wherry calls specific acidity or alkalinity rather than in terms of the P_H values. A minus sign is used to indicate alkalinity in the table (Table I). The specific acidity figure gives a better idea of the relative acidities and has the merit of yielding figures of appreciable size. Thus the difference between P_H7 (neutral) and P_H6 or P_H8 appears to the eye as one unit, yet the latter are respectively 10 times more acid or more alkaline than the former.

TABLE I. AVERAGE SPECIFIC ACIDITIES OF SOIL AND WATER IN DUNES REGION OF PORTER COUNTY.

Lake Michigan	—10
Artesian well, opposite Tremont, near Prairie Club Trail	—10
Pump well at Drive-Inn Cottage, Waverly Beach	10
The same water after boiling	—10

[2] As *Betula papyrifera, Thuja occidentalis* and *Cornus canadensis* in this swamp are close to their southern limits in this general region and are essentially northern plants a number of temperature readings of the soil were made on July 22, 1923, to see whether there were any local differences in temperature between the Tremont and the Mineral Springs swamps. The readings were made with a centigrade chemical thermometer about a foot long and inserted into the soil its entire length. The results of these readings showed a soil temperature in each swamp of about 18° C. Possibly the readings should have been taken at greater depth and have been made on a series of days. Those obtained were all made on one day, in the Tremont swamp earlier in day than in the Mineral Springs swamp which botanically should have been the cooler. The air temperature in the shade at 11 A. M. was 29° C. and at 3 P. M. 26° C.

[3] Rand McNally's Map of Indiana Dunes by P. S. Goodman.

Dune Creek, near Waverly Beach	1
Opposite Tremont	1
At an intermedite point	1
A small south tributary opposite Tremont	—10
Fore-dune region (*Calamovilfa longifolia, Prunus pumila*)	—7.7
Wooded dune, exposed sand	1
Average of several places covered with vegetation	6
Arctostaphylos uvaursi patches, usually	3.16
Wooded swamp of Dune Creek, opposite Tremont	1
Wooded tamarack swamp, opposite Mineral Springs	4
East end of same amid *Salix amydaloides*	7.7
Open swamp between the two preceding wooded swamps	30
Quaking bog, south edge of tamarack swamp	1.4
Boggy meadow, south end of Little Lake (*Drosera intermedia*, etc.)	83
Water in a "pitcher" from each of four different specimens of *Sarracenia purpurea*	—10 — 3.16 1 3.16

Essentially the same phenomenon illustrated by the difference of plus 10 to minus 10 in the case of the raw and boiled water of the pump well was noticed in preparing the distilled water used in mixing with the soils for making P_H determinations. The water distilled was from the city water supply of South Bend and issuing from the still is P_H6. Boiling this distilled water renders it P_H7. In the distilled water and in the water of the pump well the acidity is evidently due to presence of CO_2.

The extreme variations seen in the water of "pitchers" of pitcher plants, $P_H6.5$ to P_H8, may perhaps be accounted for, in part at least, by the activities of mosquito larvae living in them or by an ammonical decomposition of dead larvae. All four of the "pitchers" seemed to contain about the same number of living mosquito larvae.

The difference in specific acidity between the wooded swamp of Dune Creek opposite Tremont and the tamarack swamp opposite Mineral Springs is so small that it is probably an unimportant factor in the botanical differences between them. It is perhaps due to the better drainage of the former than of the latter.

Summary.—The water of Lake Michigan and of an artesian well near it have specific alkalinities of 10. This alkalinity appears to extend into the fore-dune area. Exposed sand of the higher dunes appears to be neutral. The wooded swamp flooded and drained by Dune Creek and Dune Creek itself is essentially neutral. The botanically different tamarack swamp about two and a half miles farther west with no very obvious drainage is slightly acid, specific acidity of about 4. A boggy interdunal meadow, without drainage and with several characteristics plants is distinctly acid, specific acidity of about 80. The soil of wooded dunes where covered with vegetation has a low but distinct specific acidity. There is a correlation between the kinds of plants growing in soils or waters of different P_H values but the differences

in such values do not appear to be as great as the differences between the plants might lead one to expect. The water in "pitchers" of pitcher plants varies from weakly alkaline to weakly acid.

NEW RECORDS OF INDIANA MAMMALS.

MARCUS WARD LYON, JR., South Bend.

The following new records within the state for Indiana mammals are only such as might be expected and as have been predicted, however the range of two species is extended to the northern boundary of the state and one species will probably be exterminated from the state within the next few years so that it seems worth while to make note of them. With the exception of the coyote the records are based on specimens which have been deposited in the United States National Museum and the National Zoological Park.

Masked Shrew, *Sorex personatus* Geoffroy St. Hilaire. Two specimens from Porter County caught in mouse traps baited with bacon placed in the quaking bog at the south end of the tamarack swamp opposite Mineral Springs Station of the Chicago, Lake Shore and South Bend Railway. They were taken in the last week of October, 1923. The vegetation where the traps were placed consisted of tall rushes, sphagnum, cranberries, pitcher plants, etc. The bog is very wet and when standing in it one's feet are always in an inch or more of water. Traps placed in the drier adjacent wooded swamp yielded only northern white-footed mice. Several specimens of this mouse were also taken in the line of traps which caught the shrews. The nearest previous record in the state appears to be Logansport[1].

Coyote or Prairie Wolf, *Canis latrans* Say. The South Bend Tribune of March 5, 1923, second section, page 1, contained a brief note regarding the St. Joseph County Commissioners having paid a bounty on a wolf. Following up the newspaper's information showed that Messrs. August Buysse and C. Sargent while hunting foxes in the southwestern part of St. Joseph County had followed an animal trailed by their dogs and shot it about ten miles west by south of the city limits of South Bend. It proved to be a female coyote. I had the opportunity of seeing the skin. It is probable that this wolf wandered into St. Joseph County from certain tamarack swamps in the Kankakee Valley, Laporte County where residents say wolves occur. Coyotes have been previously recorded from Laporte County and two specimens from Jasper County are in the United States National Museum[1] killed in 1906. Inquiry at the office of the county treasurer showed that no bounties on wolves had been paid in St. Joseph County, at least in recent years, aside from the present one. Some fox bounties were said to be paid nearly every year.

Jumping Mouse, *Zapus hudsonicus* (Zimmermann). One specimen from Porter County in the large subdunal meadow just south of the

[1] Hahn, Walter Louis, Mammals of Indiana, 33d Ann. Rept. Dept. Geol. Nat. Resources Indiana, 1908.

dunes between Port Chester and Mineral Springs stations of the Chicago, Lake Shore and South Bend Railway. The nearest previous records appear to be Newton and Starke counties[1]. It was caught in a trap baited with bacon on the night of October 26 when the minimum temperature was 47° F. The minimum temperature on the nights of October 21 and 22 was 26° F. On the intervening nights the minima were 50°, 52° and 50° F. These mice apparently do not hibernate with the first freezing weather.

Franklin Ground-Squirrel, or Spermophile, *Citellus franklini* (Sabine). Two specimens from Walkerton, southwestern corner of St. Joseph County given to me by Dr. Matthew S. Denaut of Walkerton, one in September and the other in October, 1923. One is a skin and skull in the National Museum and the other a living specimen in the National Zoological Park. This species appears to be extending its range eastward. In 1908 Hahn[1] recorded it from Jasper, White, Newton and Porter counties, in the later from the southeast corner. Agriculturists about Walkerton state that the species is not common enough to be of economic importance.

RELATION OF INSECTS TO HUMAN LIFE AND TO THE SCIENCES.[1]

J. J. DAVIS, Purdue University.

It was recently remarked that a scientist is one who tells us something which everyone knows, in a language which no one understands, this originally being given by a distinguished ecologist as the definition of ecology. It is not my purpose to talk on technical investigations but rather to discuss a general problem that we may better understand the science in which I am interested, the relation it bears to the science which each of you are interested in, and how we may better correlate and utilize our knowledge. I feel certain that if I were more familiar with the general subject which each of you are specializing in I could correlate my own work to better advantage. We are already doing this in the purely agricultural sciences, as I hope to point out later.

It rarely occurs to one that the innumerable little crawling and flying creatures known under such names as bugs, beetles, flies and worms, belong to the dominant order of living creatures. The dominance of insects—"is another way of saying that the number of fixed variations of structure, form, color, and the like, to be found in insects is greater than that presented by all other land animals. By reason of this extraordinary power of variation, and hence of adaptation—of fitness to various conditions and situations—insects are very widely distributed, and are found in a greater variety of places and surroundings than any other class of land animals on the earth. They are able to maintain themselves, in other words, in a greater number of ways and to avail themselves of a larger variety of the resources of the earth than any other animals" (Forbes). Insects "are small, extremely tenacious of life and endowed with such great powers for reproduction and multiplication that the abundance of any particular species responds very rapidly to changes in food supply, or other variable factors in their surroundings" (Brues). We all know that now and then some section of the country is overrun with grasshoppers, that chinch bugs ruin the corn in some regions, that the army worm may appear suddenly and practically denude certain regions of vegetation. These are only conspicuous manifestations of a struggle that goes on everywhere and continually in which insects are always threatening to devastate the earth and we fail to see or recognize the innumerable insects which are ready to show their voracious habits and become destructive should conditions, either weather, methods of farming and the like, or unfavorable conditions for their natural enemies, favor them. We fail to recognize the battles between harmful insects and their natural enemies which are going on everywhere about us; we fail to realize the fact that insects are not only destructive to crops and animals, and are annoying pests, but that they carry innumerable diseases of plants, of animals and of humans, and that because of this latter fact render some parts

[1] Presented at the 1922 meeting. Contribution from the Department of Entomology, Purdue University.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

of the earth uninhabitable to man, while their continued attacks on certain crops makes farming hazardous and in some sections unprofitable.

According to the latest authorities there are 470,000 described species of insects and no less an authority than the late Dr. David Sharp is responsible for the following statement: "The largest insects scarcely exceed in bulk a mouse or a wren, while the smallest are almost imperceptible to the naked eye, and yet the larger part of the animal matter existing on the lands of the globe is in all probability locked up in the forms of insects. Taken as a whole, they are the most successful of all the forms of terrestrial animals". The numbers of insects are beyond computation. Fortunately there are many checks on the increase of insects and probably only a little change in nature's balance of power would be sufficient to make the earth a desert, or as was so aptly put by one eminent scientist "If the insects would quit fighting among themselves, they would overwhelm the whole vertebrate series". In his recent address as retiring president of the American Association for the Advancement of Science, Dr. L. O. Howard emphasized these points in the following words: "Vertebrates, culminating in man, have acquired the bodily structures which, with man guided by the equally acquired intelligence, has enabled him to accomplish the marvels which we see in our daily existence. And, too, the Articulates have in the course of the ages been modified and perfected in their structure and in their biology until their many appendages have become perfect tools adapted in the most complete way to the needs of the species; until their power of existing and of multiplying enormously under the most extraordinary variety of conditions, of subsisting successfully upon an extraordinary variety of food, has become so perfected and their instincts have become so developed that the culminating type, the insects, has become the most powerful rival of the culminating vertebrate type, man".

When we speak of entomology nowadays we usually refer to economic or applied entomology. That we are beginning to realize that insects are among our most important rivals in nature is evidenced by this understanding of entomology and by the additional fact that the war against insects has become a world-wide movement in which the United States leads. In the States the federal government has a large force of workers, the Bureau of Entomology supporting 400 workers, and each state has its corps of expert investigators and every agricultural college its corps of instructors in entomology. In the American Association of Economic Entomologists alone there are nearly 800 members, practically all of whom are working on one or more phases of economic entomology. This development has come in the short space of one hundred years and principally in the last quarter of this century. Even as late as the 80's and even later entomology was considered a hobby, and the entomologist held up to ridicule. I recall a story by Dr. Leland O. Howard to the effect that in the fall of 1878, on his way from Ithaca to Washington to accept his first appointment as assistant entomologist in the U. S. Department of Agriculture, he stopped in New York to call on relatives. Among them was his grandmother

who was then 78 years old and whose sons were all big merchants and prominent citizens of New York. Dr. Howard reported a very pleasant visit with his grandmother and after he left she is reported to have said, "Leland is a good boy, but I do wish he was not in such a trifling business".

I wish to discuss principally the importance of insects, the developments in insect control and the relation of entomology to other sciences.

We have already pointed out that insects cause enormous losses. The most recent estimates place the annual losses caused by insects in the United States at $2,000,000,000, an amount equal to $20 for every man, woman and child in the States. If we prorate this loss to the farmers and others on whom the burden largely rests the cost per farm or farmer per year would of course be many times this amount. Insects play a part in every phase of life. The direct damage to growing crops is everywhere evident and conspicuous. But we have also the host of insects which attack stored products, those which affect animals, the various annoying pests, and by no means least, those which carry diseases of various kinds—the sucking insects which carry mosaic and other plant diseases, the ticks and lice, which transmit disease among domestic animals, and the various insects which are responsible for the transmission of numerous diseases of man.

In the past fifty years there has been a marked increase in the numbers of insect pests and at the present time there appears to be no lessening of this gradual increase. A common question is, why are insects more abundant than formerly? This is explained in several ways: We may assume that before civilization there was among animals and plants a natural balance which swayed back and forth but which usually balanced fairly evenly. Civilization has brought about unnatural conditions which have interfered with the natural balance and it has been necessary to utilize artificial measures to restore the balance. This interference is due to a number of causes, principal of which are:

1. Extensive and continuous cultivation of the same or related crops, is favorable to insect reproduction by offering unlimited food supplies continuously year after year; for example, the corn root aphis and corn root worm become most severe when corn follows corn, or the various clover pests which attack only legumes and which appear to be increasing in importance.

2. Transfer from native to cultivated hosts, which may have been due to the eradication or reduced supply of the native host or to a greater preference for the cultivated and usually more succulent host. Thus, we have the chinch bug attacking cultivated plants of the grass family, the colorado potato beetle whose native host was the wild Solanum, the curculio which existed only on wild fruits before cultivated varieties were introduced, and one of recent importance to roses in greenhouses, the rose root worm, which at one time attacked only wild species of Rosaceae.

3. Transportation has had much to do with the economic entomology of the United States. More than half of our most destructive

pests are of foreign origin. These are not necessarily pests of prime importance in their native home but brought here and finding favorable breeding places with the absence of their natural enemies they are capable of increasing with scarcely any restriction. Notable examples include the Hessian fly, San Jose scale, Oriental peach moth, currant worm, cabbage maggot, cabbage worm, wheat midge, European corn borer, gypsy and browntail moths, Japanese beetle, cotton boll weevil, pink bollworm and elm leaf beetle. Even within our own country transportation has had a marked influence on the spread of insect pests. Thus the San Jose scale, first introduced into America at San Jose, California, from China, was carried on shipments of nursery stock, across the entire continent to New Jersey, from which place it was soon distributed on plants to many other sections of the country.

4. The reduction of certain insectivorous birds and mammals is no doubt a factor in the abundance of insects. Increase in population, reduction of forests and hunting have had their influence on the numbers of useful birds and mammals.

Insects are grouped from the standpoint of control in several ways. From the point of view of control by insecticides, they are usually grouped according to the type of mouth parts, i. e., those with suctorial and those with mandibulate mouth parts. From the agricultural standpoint it is desirable to class insects as monophagous (restricted to a single host), oligophagous (dependent on several, usually related species of plants), and polyphagous (feeding on many species of plants). Monophagous insects are usually the most uniformly destructive but probably more readily controlled and are usually more amenable to control by good farm practices. These and other groupings are adopted occasionally for specific uses and while arbitrarily arranged they serve a useful purpose.

Before proceeding with a discussion of insect control problems I wish to call attention to the fact that all insects are not harmful. Fortunately many are directly or indirectly beneficial. Of all described insects approximately half or 225,000 are phytophagous, feeding directly upon the tissues of various plants. Of course, only a small percentage of phytophagous insects affect cultivated crops or plants useful to man but even in recent years many which originally attacked only wild hosts have gone over to cultivated crops and we may anticipate increasing numbers of such transfers. Of the remaining 50 per cent, most of which are beneficial, about 30 to 35 per cent are parasitic or predaceous on other insects, probably 17 per cent are scavengers, a comparatively small number are beneficial as producers—honey-bee and silk worm—and a few, principally bees and similar nectar-feeding species, as pollenizers.

Practically all insect controls are based on our knowledge of the structure, life history and habits of the insect in question. For convenience we may divide methods of control into two main groups and each of these into smaller groups.

I. Natural Controls
   a. Climatic controls
   b. Natural enemies

II. Artificial Controls
- c. Farm practices
- d. Mechanical devices
- e. Insecticides.

I. As a rule natural controls are not at all or are not readily utilizable artificially, although a knowledge of these control factors will enable one to assist the factors which are optimum for minimizing insect troubles.

(a) Climatic control includes all climatic factors having a definite relation to the absence or abundance of this or that insect. These factors include winter conditions, humidity, soil moisture, precipitation, wind and seasonal weather.

(b) Natural enemies are important factors in minimizing insect abundance and not infrequently of suddenly checking insect outbreaks. However, aside from the control by parasites or predators in nature, little has been accomplished. The introduction of parasites of exotic insects accidentally brought into this country is simply an atempt to renew the balance as it occurs in the native home of the insect pest and is a very profitable and desirable activity. Many examples are available. The cottony cushion scale, introduced into California, threatened to wipe out the citrus industry in that state but the introduction of certain lady-bird beetles from Australia checked it and apparently has ever since held the scale pest in thorough control. The parasites and predatory enemies of the browntail and gypsy moths are playing a significant part in holding these pests in check and minimizing spread. The digger wasp parasite introduced into Hawaii has completely subdued certain foreign grub worms which a few years ago threatened to make cane-growing unprofitable. This list of examples could be increased many times. Only recently has much attention been directed toward artificially utilizing these natural enemies.

Under natural enemies are included not only the insects which are parasitic or predaceous on harmful insects but also the many birds and mammals which prey upon insects. We would also include insect diseases which are endemic and epidemic.

II. Artificial controls may be conveniently grouped into three divisions, control by (c) farm practices, (d) mechanical devices and (e) insecticides. At the present time we immediately think of insecticides as the most important of the insect controls. However, too little attention has been given the important subject of farm practices. In the orchard, greenhouse or vegetable garden it is possible to utilize more or less costly insecticide treatments but such is not usually true in the case of general farm crops such as corn, wheat and clover which are grown less intensively and where the cost of spraying might absorb all profits. Here, then, we must usually adopt certain so-called farm practices. Even in the orchard, the vegetable garden and elsewhere, the farm practices—orchard and garden practices—are becoming more and more recognized as factors deserving of more attention.

(c) Control by farm practices refers to the practices which are or may be a part of the ordinary farm operations such as cultivation,

rotation, time of sowing or planting, time of harvesting, trap crops, clean culture, plant stimulation and drainage. As a matter of fact, it is true, as a rule, that all farm practices which are useful in preventing insect trouble are good practices regardless of the insect question. Thus, damage by the corn root aphis and corn root worm, two notoriously serious corn pests, is prevented by rotation, i. e., by not growing corn two or three successive years on the same ground—a good agronomic practice. Injury by the Hessian fly is prevented by sowing wheat after the flies issue and disappear, which date happens to be the best date for wheat sowing regardless of the fly. Most species of wireworms inhabit low, poorly drained ground and their occurrence in destructive numbers may be prevented by proper drainage, pre-eminently a good farm practice. We could recount many examples of insect control by farm practices but these few examples will illustrate the importance of this method of preventing insect losses. Even in lines of agriculture other than general farm crops, good practices are becoming more and more important in insect control. In orcharding certain farm practices play an important role in the control of such insects as the curculio. The animal husbandman finds it of greatest importance that he use sanitary measures and keep his animals in prime condition to best overcome the numerous parasites which may infest his stock. Undoubtedly farm practices are becoming more important phases of insect control and we may anticipate their increasing use in years to come.

(b) Mechanical methods, other than equipment used in applying insecticides, are less frequently utilized although we have a few prominent examples. The control of insects by hand picking may be considered a mechanical means and is probably our most primitive method. Our common house screens for which the people of the United States expend perhaps $50,000,000 each year are mechanical controls. A specially built cage-like affair, called the grasshopper-catcher, has been utilized to large advantage in many sections of the country for the control of grasshoppers. Banding trees to protect them from such insects as canker worms is a familiar example. The use of barriers to protect corn from the chinch bugs as they migrate from small grain fields, the use of tarred felt disks to protect cabbage plants from maggots, the various fly protectors used on domestic animals, sticky fly paper and fly traps, are common examples of this method of insect control.

Although the mechanical devices such as are mentioned are apparently simple they involve thorough investigations into the biological principles and the thorough use of scientific facts. The same is true in the case of the general farm practices. The application of the biological and chemical controls themselves explain the scientific principles which must be considered.

(c) Control by insecticides is by far the most generally effective of the artificial insect controls, but it was only within the last half of the nineteenth century that appreciable progress was made. This was due largely to the ignorance and superstitions regarding insects which prevailed. Even as late as the fifteenth and sixteenth centuries the control of insects was a church problem. Literature refers to church trials of insects and their excommunication from the church because of

their depredations. The early efforts in protecting crops by use of so-called insecticides, consisted largely in treatments with soot, ashes, lime and a host of other materials. Some of the earlier recommendations included as many as six or a dozen ingredients. A typical formula recommended in 1779, for mealy bugs, was:

Sulphur	8 ounces
Scotch snuff	8 ounces
Hellebore powder	6 ounces
Nux vomica	6 ounces
Soft soap	6 ounces
Cayenne pepper	1 ounce
Tobacco liquor	1 quart
Water, boiling	1 gallon

The author of this recipe was evidently not entirely confident of is effectiveness for he recommends that the plants be washed with the decoction and that the insects be removed while washing.

The real advances in insecticides have been the result of specific insect problems. The Colorado potato beetle and cotton worm brought about the introduction and use of Paris green. The development of arsenate of lead was the result of problems connected with the gypsy and browntail moths. The seriousness of the San Jose scale brought about the development of the miscible oils and lime-sulphur. Other needs have had an influence on the development of insecticides. Thus the need of standardized tobacco extracts has resulted in the manufacture of standard strengths and made available the practical use of this most valuable insecticide. Similarly the poison gases, used during the war, have opened our eyes to their possible utilization.

There is a vast field for the properly fitted chemist for the development of new insecticides and new phases of present day insecticides. There is likewise a large field for the engineer, for the application of insecticides is itself as important a problem as the preparation of insecticides.

We spoke of the relation of entomology, and particualarly economic entomology, to the other branches of science. As Dr. S. A. Forbes has said: "It is when we search for specific reasons for our successes here and our failures there that we are driven to a scrutiny and analysis of controlling conditions of every description, and so find ourselves involved in studies so far outside entomology, commonly so-called, that we are obliged to apply for assistance to the physiologist, and the chemist, and the physicist, and the meteorologist, and the geographer, and the agriculturist, and the animal husbandman, and the bacteriologist, and the physician, and the sanitarian, or in a word, to the ecologist, who from the nature of his studies, must, if he is to thoroughly cover his field, be something of each and all of these and still something more." As is true with every other science the field of entomology is broader than is generally supposed. In the study of insecticides the entomologist must have a thorough knowledge of the science or the assistance of the chemist, the plant physiologist, the horticulturist, and the meteorologist and in development of means of application the services of the engineer

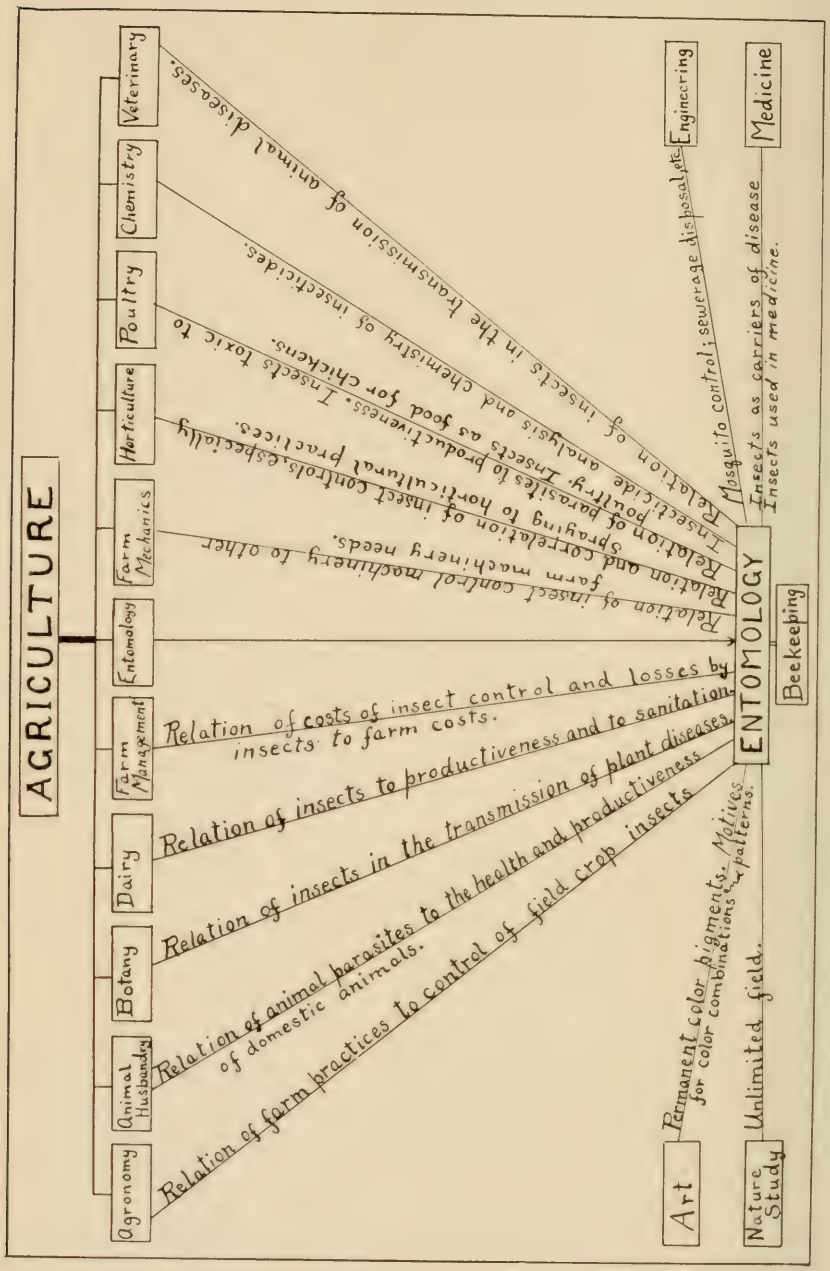

AGRICULTURE
Agronomy
Animal Husbandry
Botany
Dairy
Farm Management
Entomology
Farm Mechanics
Horticulture
Poultry
Chemistry
Veterinary
Relation of farm practices to control of field crop insects
Relation of animal parasites to the health and productiveness of domestic animals.
Relation of insects in the transmission of plant diseases.
Relation of insects to productiveness and to sanitation.
Relation of costs of insect control and losses by insects to farm costs.
Relation of insect control machinery to other farm machinery needs.
Relation and correlation of insect controls, especially spraying of poultry parasites to horticultural practices.
Relation of poultry insects as food for chickens.
Insecticide analysis and chemistry of insecticides.
Relation of insects in the transmission of animal diseases.
Art
Permanent color pigments. Motives for color combinations & patterns.
Nature Study
Unlimited field.
ENTOMOLOGY
Beekeeping
Engineering
Mosquito control; sewerage disposal etc.
Medicine
Insects as carriers of disease
Insects used in medicine.

Fig. 1. The relation of entomology to the sciences, and to agricultural subjects in particular.

are essential. The application of farm practices, including as it does methods of growing and handling crops, involves the engineer in the case of drainage, the agronomist in such practices as rotation and cultivation, the crops expert in the study of resistant varieties, the animal husbandman in the problems connected with animal parasite control, the physician and veterinarian in the study of insects and disease, and the botanist in the study of insects and plant diseases. Even the lawyer becomes involved when we consider entomology in its broadest sense, for the present day inspection, insecticide and quarantine laws require his services in more ways than one. In this connection, the accompanying figure (fig. 1) will give an idea of the relation of insects to other sciences, particularly to the agricultural sciences.

Just a final word regarding the work of the entomologist. We might for convenience group it into four divisions: (1) Teaching, (2) Extension, (3) Investigation and (4) Regulatory.

1. **Teaching.** In teaching work two classes of students are involved. First, those who require it as a part of their course in agriculture, forestry, sanitary engineering and the like, and who desire such information about insects, their recognition and control as should be of most practical value to him in his future work and to lead him to acquire a foundation in the principles of entomology that will serve as a guide in solving new and unexpected entomological problems or applying the knowledge gained to his particular conditions. Second, those who wish to fit themselves for professional work in entomology.

2. **Extension work.** Under extension work we might include demonstration of control measures, newspaper and bulletin publicity, farmers' institutes and the like. Extension or demonstration work must be considered an important feature of the entomologist's routine. In the past there was some question as to whether extension was a part of the entomologist's work. I recall a story related by S. A. Forbes. A few years after taking up the work as entomologist of Illinois, Forbes noticed that although he had accumulated and published the results of many investigations and had thereby furnished in writing the methods of controlling or subduing certain insect pests, the farmers seemed to make little use of his results. He called the attention of this matter to Richard Oglesby, then governor of Illinois, and pointed out that further means should be taken to induce farmers to use better methods of control. The governor's reply was to the effect that whether or not the farmer made use of his recommendations was none of his (Forbes') business, that his responsibility ended when his work was done to the best of his ability and he had published his results in the form and manner provided by law. Then, to illustrate his point, he thanked heaven that his own responsibility ended when he had made his recommendations, in his annual and special messages, to the legislative bodies, and that he was not himself responsible for the acts of the state legislature. In his address as president of the American Association of Economic Entomologists in 1893, Doctor Forbes emphasized the fallacy of this policy in the following words: "It is not the facts of entomology we discover, but those which we persuade the farmer,

the gardener or the fruit-grower to use diligently for the protection or the preservation of his crops, which make our entomology economic. To publish valuable results without making sure of their appreciation and appropriation by our constituents, is to fail of real usefulness. To bring a result to bear on the practice of one man only when a thousand are suffering for the want of it, is to fail in 99.9 per cent of our proper undertaking. We must first do exact, exhaustive, conclusive, practical, economic work, and then we must find means to get that work utilized or it is an economic dead loss".

The correspondence of the entomologist may be considered as extension work and is not routine as might be generally supposed. The three steps in insect control are diagnosis, prescription and application. Thus every inquiry must be handled as an individual case and must be diagnosed and information furnished accordingly, much as a physician would diagnose a human ailment. The third step in insect control—application—is of course dependent on the person who must apply the remedy and too often the remedy proves ineffective because of faulty application—as poor or improper materials, or equipment, or lack of timeliness or thoroughness of application.

3. **Investigation and Research.** The investigation and research problems in economic entomology include various phases of work. First of all the investigator must have a thorough knowledge of the facts connected with the method and type of injury. A general study of the life history and habits of the insect must be made and this ordinarily must be followed by a complete and careful study of the various phases of the life of the insect and of its habits which may necessitate detailed studies, including studies in tropisms, ecological relations and the like. These may be very simple or more likely complex investigations. The life history must be studied from all angles and under the possible varying conditions, and the results of these studies used as a basis for theoretical controls. These theoretical controls must be tested first in a small way and sometimes it is necessary to test out hundreds of materials or methods before likely controls are found. The most likely methods of control as determined by the small plot tests are then tried on a large scale and these we term field tests or experiments. In all control work it is essential that the entomologist be in constant touch with the agronomist, horticulturalist, botanist and forester in order that his recommendations may not be at variance or interfere with the most approved farm practices. The discovery and formulation of methods of controlling or subduing insect pests is of course the prime function of the economic entomologist. In all experimental work, it is essential, if truthful, dependable and lasting results are to be obtained, for the investigator to exercise the highest degree of fairness and accuracy in recording and interpreting results, and to eliminate or at least make due allowance for any disturbing or unnatural influences which may enter into the problem.

4. **Regulatory.** We may include under this heading all activities having to do with the enforcement of laws pertaining to entomology, such as nursery inspection to protect the orchardist against the intro-

duction of certain serious pests, apiary inspection to protect the bee-keeper against foul-brood and other troubles, insecticide regulations to guard against inefficient insecticides, and quarantine regulations to protect the state or sections of the state from new insect pests or those not generally distributed.

Supplementary to the studies already mentioned, the entomologist must have a thorough knowledge of insect classification and be able to identify the thousands of insects which come to his attention annually. The importance of immediate and correct identification of insects is of vital importance and while the common and usual insects are readily identified those occurring periodically, those of uncommon occurrence, and those foreign to the state or nation can usually be identified only with the assistance of a reference collection.

The work of the entomologist's office has many features in common with that of the weather forecaster. We are gradually assuming the rôle of insect forecasters and I believe it will be only a comparatively short time until the entomologist will be able to forecast with reasonable certainty the likely occurrence in destructive numbers of this or that insect. This is already possible in the case of some of our common pests, such as the wheat jointworm, Hessian fly, white grub, chinch bug, periodical cicada and others. Forecasting necessitates a careful study of the past history of insect outbreaks, their causes, the relation of croppings, weather, parasites and the many other factors connected with insect life. In other words, with the forecasting of insect trouble as an important routine of the entomologist's office, we find that the entomologist must be an ecologist and have a working knowledge of the fundamental principles of the various branches of agriculture and other sciences. This phase of entomology further illustrates the intimate connection which it bears to all phases of human life.

The entomologist must ever be alert for pests foreign to the state or nation. Probably a majority of our major insect pests are of exotic origin and it is noteworthy that many of these pests are not of any great importance in their native habitat so that we cannot always depend on the status of an insect in its native home as a criterion for its acts in America.

And finally, what is the future of insect control? Certainly the kinds of insects attacking our cultivated crops are going to be more numerous in the future. Insecticides are now the major methods of direct control and they will continue as essentials to insect control but we will need to make further and more intensive investigations to find cheaper and more effective materials and methods. The cultivation of resistant varieties is likely to be an important feature of future insect control but above all the further development of insect control by farm practices and by the biological method—control by natural enemies—are certain to be among the most important factors in insect control work a hundred years hence.

NOTES ON THE TERMITES OF INDIANA—II.[1]

HARRY F. DIETZ, State Department of Conservation, Indianapolis[2].

In 1920[3], the writer reported for the first time the occurrence of *Reticulitermes virginicus* Banks in Indiana. He also called attention to the fact that careful collections should reveal the presence of another species, *R. hageni* Banks in this state. Life history notes and data on the economic importance of the only previously recorded species in Indiana, *R. flavipes* Kollar, were also presented. At that time nothing was known about the distribution and economic importance of *R. virginicus* in this state.

Since 1920, twenty cases of termites' damage have been investigated by the writer in response to requests received by the Division of Entomology of the State Department of Conservation for help in eliminating these pests. Of these, eleven were *R. flavipes*, eight were *R. virginicus* and one was *R. tibialis*, a new record for Indiana.

Distribution.—To the known distribution of *R. flavipes* in Indiana the following localities were added: Morgantown, Richmond, Switz City, and Terre Haute.

R. virginicus has only been found in Indianapolis.

The only record of *R. tibialis* is from the southwest corner of Gibson County, four miles north of Poseyville. From published records[4] this species seems to be a western one, the nearest point to Indiana recorded being Iowa City, Iowa.

Swarming.—The records of the swarming of *R. flavipes* during 1921 and 1922 followed those recorded in 1920 very closely, ranging from April 9 to May 15.

All specimens of winged colonizing adults of *R. virginicus* have been obtained between March 16 and April 8, 1922. In all cases the swarms occurred in buildings and were therefore independent of out-of-door conditions.

No specimens of fall swarms of either *R. flavipes* or *R. virginicus* have been obtained and several cases of such swarms that were investigated in 1922 proved to be the swarming of true ants. However, in the case of one dwelling infested with *R. virginicus* the owner reported that swarming took place early in October in 1921.

The one and only record of *R. tibialis* was winged adults obtained on November 3, 1922, from the crowns of strawberry plants, previously tunnelled by the workers. Whether swarming took place prior to or after this date could not be learned.

damage were reported to the Division of Entomology and investigated by the writer. In 1922, fifteen cases were reported and visited. In some

Termite Injury.—During the year 1921 only five cases of termite

[1] Presented at the 1922 meeting.

[2] Published with the permission of the Chief of the Division of Entomology and the Director of the Department of Conservation of Indiana.

[3] Notes on the Termites of Indiana. Proc. Ind. Acad. Sci., 1920, pp. 87-96 (1921).

[4] A Revision of the Neartic Termites with Notes on Biology and Geographic Distribution. Banks, N., and Snyder, T. E. Bul. 108, U. S. Natl. Mus. (Feb. 15, 1920).

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

cases extensive damage was done. Since termites often work several years unobserved in a building, it is improper to credit all damage done to a single year.

At Richmond and Morgantown certain neighborhoods were found where extensive damage was done to all surrounding wooden structures that were so constructed as to invite attack. By this is meant wood construction either in direct contact with the ground or very close to the ground. This was particularly true at Richmond where two adjacent dwellings were set not more than a foot from the ground. Besides these dwellings all fences, sheds and grape arbors were badly damaged by *R. flavipes*. Not only were the wooden structures attacked, but the heart wood of a large cherry tree and the centers of a dozen thirty-year-old grape vines were also eaten out. Besides, tunnels were occasionally made through the living wood to the surface of infested plants where the characteristic covered runways were constructed over the bark. On the cherry tree some of these runways were a foot and more in length, reminding one in a small way of the runways of certain tropical species of the genus *Nasutitermes* which build runways over the surface of high trees from the ground to the tops. Conditions such as these indicate the presence of a large central nest somewhere in the vicinity from which the insects work. At Morgantown in several localities somewhat similar conditions were found.

The most interesting case of injury by *R. flavipes* not only from an economic aspect but also from a biological one was found at Indianapolis July 12, 1922. A carpenter was repairing a dwelling over fifty years old in one of the older parts of the city and found that the termites had worked through the decomposing mortar between the bricks into oak plates made of twelve by twelve inch "flitches." Here they had constructed an accessory nest from which the writer obtained twenty brachypterous or second form queens in less than a half hour. Millions of eggs and young in all stages of development were also found. I was informed that at least twice as many of these queens had been destroyed before I visited this place.

R. virginicus is equally as important as *R. flavipes* when it comes to damaging buildings. In the northern and eastern residential sections of Indianapolis serious damage to dwellings was done in 1922 by the former species. Repairs that were necessary amounted to as high as fifteen hundred dollars in at least two cases. Some very poor types of construction were revealed such as plastered wall partitions built directly to the ground with cement floors around these walls. In this case it would have been just as easy and just as cheap, and at the same time would have been a protection against termites, to have had such walls constructed to rest on the cement floors. In another instance, in a very costly residence, the tile floor of the sun parlor was laid on one foot of cinders supported by a wooden floor. In turn in the basement some of the supports and joists on which the wooden floor was laid came in direct contact with wooden construction and ran into the round. When this poor type of construction was removed to replace it with concrete it was found that in many places the wooden floor and joists had been

badly damaged by the termites and it would have been only a matter of time until this part of the house would have collapsed.

R. virginicus has revealed an interesting fact about the use of hollow concrete blocks in building foundations. The use of such foundations as they are now generally built lays the wooden plate and other wooden construction open to termite attack as readily as if these parts were in direct contact with the ground. The reason is that these insects build their runways from the ground up to the plate on the hollow insides of the blocks. Here the insects can work unmolested for it is impossible to shut them off from the wood without extensive tearing out and putting in either solid concrete blocks or a layer of bricks laid in cement between the ground line and the plate. It is much easier to do this in the process of building the foundation than after the house has been damaged.

The conditions under which *R. tibialis* was found indicate that if it is widely distributed in Indiana it too will be a species of considerable economic importance. It was found tunnelling "mother" strawberry plants in an area of about one acre in a twenty acre field. Over this area three years previously pea hulls had been piled and rotted and it is probable that the insects had been working in this pile. The region north of Poseyville where it was found was a sandy, level, almost treeless area, with apparently nothing for termites to feed on except living cultivated plants, fence posts and wooden buildings.

Acknowledgement.—The identifications of all material collected were verified by Dr. T. E. Snyder, Expert in Forest Entomology, United States Department of Agriculture.

NOTES ON THE FUNCTION OF THE FORCEPS OF EARWIGS.

W. P. MORGAN, Indiana Central College.

"Of what use are the pincers?" is a question the writer has been asked many times. Most text-books say they "are either used as claspers in mating or as an aid in folding the wings." This answer seemed inadequate. Last summer at the Indiana University Biological Station observations were made on the use of these "pincers" or forceps. Two large species of earwigs collected in the region of St. Petersburg, Florida, were used (figs. 1 and 2) and an effort was made to secure typical action photographs. This was rather difficult, though, as subdued light was necessary to get the earwigs to react normally, and their movements were very rapid.

The writer recalls that his introduction to the question of the function of the forceps came while making dissections of some Louisiana earwigs. Some of the large insects pinched so vigorously that the points of the forceps nearly pierced the skin. Although the effect of such an attack on a person was of trivial consequences the force would probably have been great enough to crush an insect as large as the earwig. Another indication of strength was seen in the large muscles that control the forceps. It seemed unusual that such powerful organs had developed merely as claspers in mating or as aids in folding the wings, especially since many of our earwigs do not fly. Figures 1 and 2 show the powerfully developed forceps in both sexes.

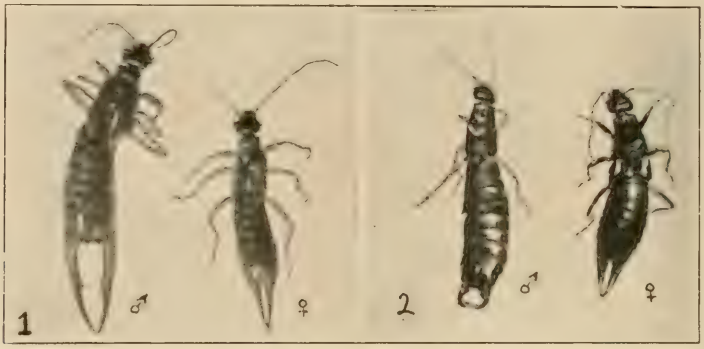
Another item that early attracted attention was the number of earwigs, especially males, that failed to survive the effect of shipping. The dry forceps of several males and a few females would be found in each shipment (fig. 4). Usually the sexes were separated as soon as unpacked and placed in large mouth bottles. It was from these segregated males that the truth of the high fatality of the males during shipment was learned to be due to cannibalism.

The method of attack was always with the forceps and the attacking earwig would either flip his body side-ways or run back into his adversary using his forceps all the time in scissor-like strokes. The earwig thus attacked would counter with his forceps and if active and strong enough the battle would resolve itself into a sparring match where the forceps were used both as weapons of offense and defense. Not only are the forceps used as pincers but many times the posterior part of the abdomen is raised, lifting the opponent clamped in the forceps, entirely off his feet. Occasionally the forceps with their victims are rotated through more than ninety degrees which often permits a more favorable hold beyond the heavily armored abdomen. The abdomen in all species examined was the largest in the region of the forceps and tapered toward the thorax (figs. 1 and 2). As soon as the pincers were clamped on an opponent the earwig would start pulling away as shown in figure 5. This gave protection to its head and thorax and often threw the other insect into a position where another

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

thrust with the forceps would mean defeat for the one being dragged. When an adversary was injured or held in a helpless position so far as the forceps were concerned the winner would twist around and use his mandibles in the softer parts of the victim's body. Figure 6 shows an earwig with a cricket in this condition.

When disturbed the earwigs often raise their forceps in a threatening manner that reminds one of the scorpions. This position seems to



Figs. 1-2. Mounted specimens of the two types of earwigs used in the experiments. Note the powerful forceps. Slightly enlarged.

give protection to the thoracic region and is favorable to a more accurate thrust with the forceps. When this method of attack is used the earwig raises the posterior part of its thorax to an angle of nearly forty-five degrees so that the forceps are brought to a location directly above the head. While running forward in this position the thrust is made in a slightly lateral direction (fig. 3) enabling the earwig to turn the

Fig. 3. A male earwig in a scorpion-like position of attack. The forceps were in a position above the head until the "stroke" was made in a lateral direction.

anterior part of its body into a place of safety but still giving battle with the pinching thrusts of its forceps. Some observers have attributed these scorpion-like actions to mimicry but this does not seem to be the case.

The males are more pugnacious than the females but cannibalism is very common among females placed in containers with only a small amount of food. Figure 7 shows a female eating a cricket that it has

just killed with its forceps. So viciously did this female attack the cricket that one of its large legs was torn off with the first blow.

Various insects and small crustacea were used in experimenting with the earwigs, but the cricket was chosen as the most favorable.

With the exception of the most pugnacious the males are very timid and are the first to scamper away when disturbed. The young males are especially timid and apparently stay in hiding most of the time. This probably accounts for the few very young males collected. Most of the older males were battle scarred and it was seldom that a specimen did

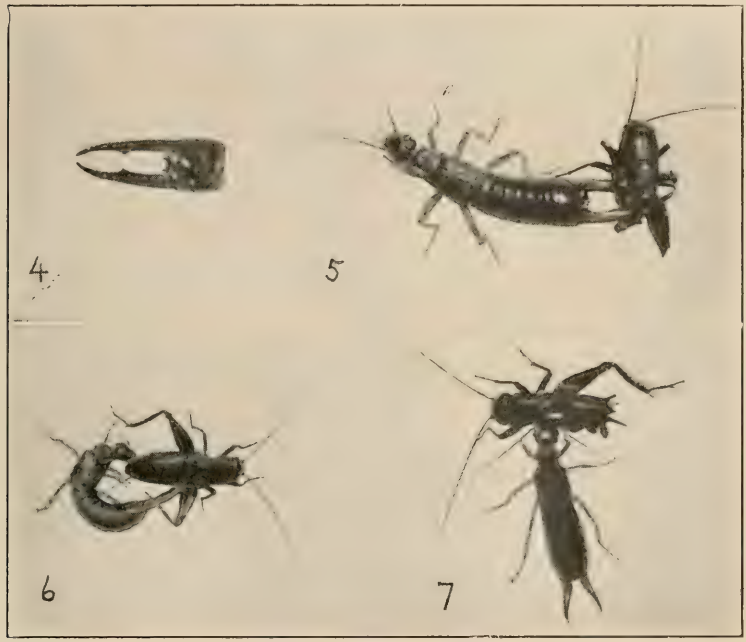


Fig. 4. The forceps of a male. All that was left of a victim of cannibalism.
Fig. 5. A male dragging a cricket which it has killed with its forceps.
Fig. 6. Eating the prey, a cricket, that is being held by the forceps.
Fig. 7. A female eating a cricket that it has just killed. The forceps are held in a characteristic position.

not lack part of an antenna or parts of one or more legs. Mr. N. P. Fry who collected the Florida earwigs said he was able to collect more than three times as many females as males. The ratio of males in shipment, including those killed during shipment, was about the same in all species used. The fighting among the males probably reduces their numbers but the difficulty in collecting them due to their being more timid than females is a more reasonable answer to the question of sex ratio in collection.

Another indication that the forceps are important in defense as well as attack is the position in which they are held when not in use. Figure 7 shows a female with the forceps in a characteristic pose. Both

sexes are very often seen hiding with only the forceps and posterior part of the abdomen protruding from the cover. When an earwig passes such a hiding place very often these forceps push out and close and open in a threatening manner that cannot be mistaken for sex attraction. Very often the passing earwig offers fight and several such combats have been observed that had fatal endings.

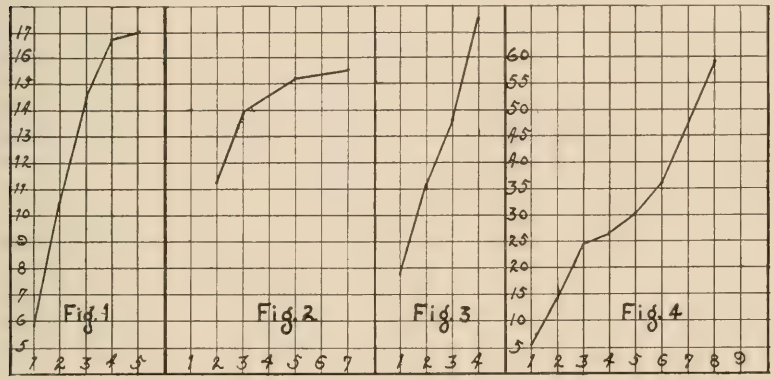
A few cases of the earwigs in sexual embrace were observed but in no instance could the forceps be seen to act as claspers. The position of the forceps during mating, though probably not of any especial advantage to the earwig, might easily have been mistaken for similar structures as found in other animals. Whether the forceps were formerly claspers which have developed into organs of combat in our modern earwigs is a question the writer is not prepared to discuss. Regardless of the former importance of the forceps or their present function in primitive forms the writer's conclusion is that they are primarily weapons, developed and used as such in all forms observed.

Summary of Observations.—1. The forceps of American earwigs are well developed and controlled by powerful muscles. Their strength is nearly sufficient to pierce the skin of a person. (2) The male earwigs are very pugnacious. (3) Earwigs are cannibalistic, especially the males. The forceps are then the chief weapons of attack. (4) The females are more apt to become cannibalistic when food is scarce. (5) Males have been observed to attack and devour females. (6) Earwigs assume a position in attack similar to the scorpions, due to convenience and effectiveness rather than mimicry. (7) They protect their head and thorax but keep the forceps in readiness for defense if disturbed. (8) Earwigs are nearly omnivorous but may attack as prey insects or small crustacea, using their forceps. (9) The forceps are often used in holding the prey while it is being eaten. (10) In no case were the forceps used in folding the wings. (11) The forceps are of little if any importance as claspers in mating.

THE RELATION OF SIZE TO AGE IN SOME COMMON FRESHWATER FISHES.

HOMER R. BOLEN, Indiana University.

On the scales of most of our common fishes are a series of concentric rings. They may be readily seen under a low power microscope. These rings form alternate dark and light bands due to being closer together in some regions than in others. The dark bands represent periods of slow growth and the light bands periods of rapid growth. Since growth is dependent upon food, the dark bands are undoubtedly formed during winter when feeding is partially suspended. Thus by counting the "winter check" bands we can determine the age of the fish.



Figs. 1-4. Graphs showing rate of growth. The abscissa is the age in years, the ordinate the average length in centimeters. 1, *Lepomis pallidus* (Mitch.), Winona Lake; 2, *L. pallidus*, Shoe Lake; 3, *Perca flavescens* (Mitch.), Winona Lake; 4, *Micropterus salmoides* (Lacépède).

During the summer of 1923, at the Indiana University Biological Station, Winona Lake, Indiana, an attempt was made to determine the relation existing between age and size of some of the common fishes.[1] Data were collected on three species: bluegill, *Lepomis pallidus* (Mitchill); yellow perch, *Perca flavescens* (Mitchill); and large-mouthed black bass, *Micropterus salmoides* (Lacépède).

All the specimens were secured from Eagle (Winona) Lake with the exception of one lot of bluegills from Shoe Lake and a few black bass from other lakes. All of these lakes are located in Kosciusko County, Indiana. Scales were secured from different parts of the body and placed in paper envelopes on which were written all the data secured on each individual, viz., date, species, weight, and length to base of caudal fin. Subsequently the scales were examined under a low power microscope and the age of the fish determined; after which the following tables (Tables I to IV) were compiled and graphs (figs. 1 to 4) constructed.

[1] This work was taken up at the suggestion of Dr. Will Scott to whom I am indebted for advice and direction.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

TABLES I to IV.

Data showing relation of size to age of three common freshwater fishes.

TABLE I.—*Lepomis pallidus* (Mitchill), Winona Lake

AGE IN YEARS	NUMBER OF SPECIMENS MEASURED		LENGTH IN CMS. TO BASE OF CAUDAL FIN		NUMBER OF SPECIMENS WEIGHED		WEIGHT IN GRAMS	
	Actual Number	Percent of Total	Average Length	Percent Increase	Actual Number	Percent of Total	Average Weight	Percent Increase
1	16	29.1	5.94	.....	14	48.2	4.14	.....
2	29	52.7	10.5	76.7	13	44.8	41.61	905.0
3	7	12.7	14.43	37.4	.....	.....	.....	.....
4	2	3.6	16.75	16.0	1	3.5	115.	.....
5	1	1.8	17.	1.5	1	3.5	170.	32.3

TABLE II.—*Lepomis pallidus* (Mitchill), Shoe Lake

AGE IN YEARS	NUMBER OF SPECIMENS MEASURED		LENGTH IN CMS. TO BASE OF CAUDAL FIN	
	Actual Number	Percent of Total	Average Length	Percent Increase
1	.....	.....	.....	.....
2	30	76.9	11.28	.....
3	7	17.9	13.96	23.7
4	.....	.....	.....	.....
5	1	2.6	15.25	.....
6	.....	.....	.....	.....
7	1	2.6	15.5	.....

TABLE III.—*Perca flavescens* (Mitchill), Winona Lake

AGE IN YEARS	NUMBER OF SPECIMENS MEASURED		LENGTH IN CMS. TO BASE OF CAUDAL FIN		NUMBER OF SPECIMENS WEIGHED		WEIGHT IN GRAMS	
	Actual Number	Percent of Total	Average Length	Percent Increase	Actual Number	Percent of Total	Average Weight	Percent Increase
1	25	32.9	7.87	.....	23	40.4	7.14	.....
2	31	40.8	11.14	41.5	23	40.4	18.67	119.4
3	19	25.	13.67	22.7	10	17.5	38.8	108.
4	1	1.3	17.5	28.	1	1.7	100.	157.

TABLE IV.—*Micropterus salmoides* (Lacépède)

AGE IN YEARS	NUMBER OF SPECIMENS MEASURED		LENGTH IN CMS. TO BASE OF CAUDAL FIN		NUMBER OF SPECIMENS WEIGHED		WEIGHT IN GRAMS	
	Actual Number	Percent of Total	Average Length	Percent Increase	Actual Number	Percent of Total	Average Weight	Percent Increase
1	3	13.8	5.5	.....	.....	.....	.....	.....
2	1	4.5	14.	154.5	.....	.....	.....	.....
3	3	13.8	24.3	73.5	1	11.1	175.	.....
4	9	40.9	26.88	10.6	4	44.4	418.7	139.2
5	4	18.1	30.12	12.0	3	33.3	566.6	35.0
6	1	4.5	36.5	14.5	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....
8	1	4.5	59.	.....	1	11.1	1,644.2	.....

These specimens were taken during a period of ten weeks in June, July and August. All species studied spawn in late spring or early summer[2]. Their ages at time of collection therefore would be a little more than whole years. The fraction is so small that it was thought advisable to consider the age as whole years.

Table I indicates that the bluegills of Eagle (Winona) Lake increase in length about 77 per cent between the ages of one and two years, about 37 per cent the next year and 16 per cent the next. The increase in weight during the second year is over 900 per cent. The bluegills of Shoe Lake (Table II) however, increase but 24 per cent in length between the ages of two and three years. The small number of specimens may be the cause of this discrepancy or there may be a constant difference in rates of growth in the two lakes. This point needs further investigation with larger numbers of specimens.

Yellow perch (Table III) showed a length increase of 41.5 per cent, 22.7 per cent, and 28 per cent respectively for the years from one to four, and an increase in weight of 119.4 per cent, 108 per cent and 157 per cent respectively for the same period. Pearse and Achtenberg[3] "believe that yellow perch become sexually mature in Lake Mendota (Wisconsin) at the end of two years' growth." Hence if they are to be given a chance to breed one season no perch less than 14 or 15 centimeters (measured to base of caudal fin) should be taken.

The numbers of black bass are too few to arrive at any satisfactory conclusions but the data are given in table IV and figure 4.

It is interesting to note, as a comparative study, the rate of growth of yellow perch in Lake Erie[4]. The two, three, and four year old perch average respectively 3.3, 3.1, and 1.2 centimeters longer than those of corresponding ages in Eagle (Winona) Lake.

This question of rates of growth is very closely linked up to other problems of fresh-water biology. It has a connection with population and food conditions of the lakes. If a species grows more rapidly in one lake than in others it indicates that the food complex is more favorable there. This may mean that the food is more abundant or that competition is less severe. A systematic investigation of rates of growth of the fishes of inland waters will no doubt reveal some very interesting facts on the fertility of our various lakes. From an economic viewpoint it will mean a better knowledge of the possibilities of our lake resources.

[2] Forbes, S. A., and Richardson, R. E. The fishes of Illinois. Nat. Hist. Surv. Ill., Vol. III, 1908.

[3] Pearse, A. S., and Achtenberg, Henrietta. Habits of yellow perch in Wisconsin lakes. Bul. U. S. Bur. Fish, Vol. XXXVI, 1917-18, pp. 297-366.

[4] Harkness, W. J. K. The rate of growth of the yellow perch (*Perca flavescens*) in Lake Erie. Uni. Toronto Studies, No. 20, 1922, pp. 89-95.

THE DIURNAL OXYGEN PULSE IN EAGLE (WINONA) LAKE.

WILL SCOTT, Indiana University.

This paper presents data which demonstrates an observable oxygen pulse in the surface water of Eagle (Winona) Lake when the weather is clear and relatively calm.

When a lake stratifies after the vernal overturn, the hypolimnion is sealed from the air and the respiration of the organisms and the decay of the organic matter gradually reduce the amount of oxygen present in this stratum. In the epilimnion the water may be circulated by the wind and consequently any part of it may be exposed to the air and may take up oxygen or give it up depending on the amount it contains. The upper levels of this region receive most of the light absorbed, so that photosynthesis is more pronounced at these levels than deeper.

In the epilimnion the amount of dissolved oxygen may be increased by absorption from the surface and by photosynthesis. It may be decreased by discharge at the surface, by respiration of organisms, and by the decay of organic matter. All of these factors that influence the amount of dissolved oxygen are continuous except photosynthesis. It occurs only in sunlight and consequently is diurnal on clear days.

So long as the amount of oxygen remains below the saturation point, it is difficult to establish the combination of factors which is responsible for the amount observed. However, when the water becomes saturated, as it often does in calm weather, it can be accounted for only by photosynthesis, modified slightly by temperature changes.

In building up high supersaturation, the increase must occur all in one day, or there must be a series of daily rises, or there must be a diurnal rise and fall in the amount of dissolved oxygen. This would be more marked near the surface on calm days. On windy days the water in Eagle Lake is mixed to such a depth (five meters in Eagle Lake) that the effect of photosynthesis is obscured.

Observations were made at two stations, a littoral and a pelagic. The littoral station was in an embayment just offshore from the Biological Station. This bay was filled with aquatic phanerogams, chiefly Potamogetons and the accompanying biota. The pelagic station was about 100 meters beyond this in the open water. The oxygen was determined by the Winkler method. The water was collected by means of a 100 cc. pipette and discharged into rubber stoppered bottles until an amount equal to the capacity of the bottle was flushed. The water was treated and titrated at once. The water was always collected within a few centimeters of the surface.

Two types of observations were made. One consisted of collections made at 9:30 a. m. and 4:15 p. m. The second type consisted of serial collections running as near 24 hours as the lake remained calm. These were very difficult to get complete. The lake might be perfectly calm in the morning and after a few samples had been taken the wind would disturb conditions so that the series would have to be discontinued.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

Table 1 shows a series of the first type that was taken in 1922 at the littoral station. The data columns give: (1) the water temperature, (2) the amount of oxygen necessary to saturate water at that temperature, (3) the amount of oxygen present in cubic centimeters per liter, and (4) the per cent of saturation. On July 20 it was slightly cloudy and in consequence slight changes occurred. The temperature increased 1.5° C., the oxygen decreased slightly (.08 cc. per liter) the per cent of saturation increased 2 per cent. On the other four days the amount of oxygen, the temperature, and the per cent of saturation increased. The average increase in temperature was 4.3 C., the increase in oxygen was 3.33 cc. per l. and saturation increased 72 per cent. While the 9:30 observations were not the minimum for the 24 hours yet the amount present at 9:30 on July 25 and 26 was greater in each case than it was on the preceding evening at 4:15.

TABLE I.

Data Obtained from Semi-Daily Observations at Winona Lake, Indiana

DATE 1922	A. M. Readings				P. M. Readings				Weather
	Water temperature °C.	Oxygen for saturation	Oxygen present cc. per l.	Per Cent of saturation	Water temperature °C.	Oxygen for saturation	Oxygen present cc. per l.	Per Cent of saturation	
July 20.....	22	6.04	7.55	121	23.5	5.89	7.27	123	Cloudy
July 21.....	22	6.04	8.37	138	29.4	5.45	10.74	196	Clear
July 24.....	21.7	6.07	5.88	96	28	5.54	9.95	179	Clear
July 25.....	27.5	5.57	5.73	135	29.5	5.45	11.27	206	Clear
July 26.....	27	5.60	6.53	117	30.5	5.40	10.47	193	Clear
Average last four days..	24.5	.....	7.07	121	29.3	.....	10.40	193	.....

We have secured three sets of serial observations taken as follows: 9 a. m. to the folowing 8 p. m.; 6:30 a. m. to 11:30 p. m.; and from 6:30 to 8:30 p. m. The first is for the littoral station alone. The other two are for both stations in parallel.

The pulse in Series 1 (fig. 1) reached its maximum at 6:30 p. m. The notch in the oxygen curve at 3:00 was due to clouds between 12 noon and 3 p. m. At 3 p. m. it was again clear and remained so. At 6 p. m. the temperature had fallen 2 C., and the oxygen had increased slightly more than 2 cc., both of which facts tended to increase the per cent of saturation. Sometime between 9 p. m. and 12 p. m. the per cent of saturation became less than 100 per cent and remained so until 8 a. m. the next day when it was exactly 100 per cent.

The lowest temperature was at 3 a. m. although it probably became slightly lower between that hour and sunrise.

In Series 2 (fig. 2) the maximum occurred at 3:30 p. m. at the pelagic station and at 5:30 at the littoral. The amount of oxygen at the pelagic station at 6:30 p. m. exceeded the amount at the littoral station. This condition was again reached at 9:30 p. m. and 11:30 p. m. Between 6:30 a. m. and 9:30 p. m. there was more oxygen at the lit-

toral station than at the pelagic station. In other words the maximum is greater and the minimum less at the littoral station than at the pelagic. This means that there was more photosynthesis on the one hand and more respiration and decay on the other in the dense population of the littoral station.

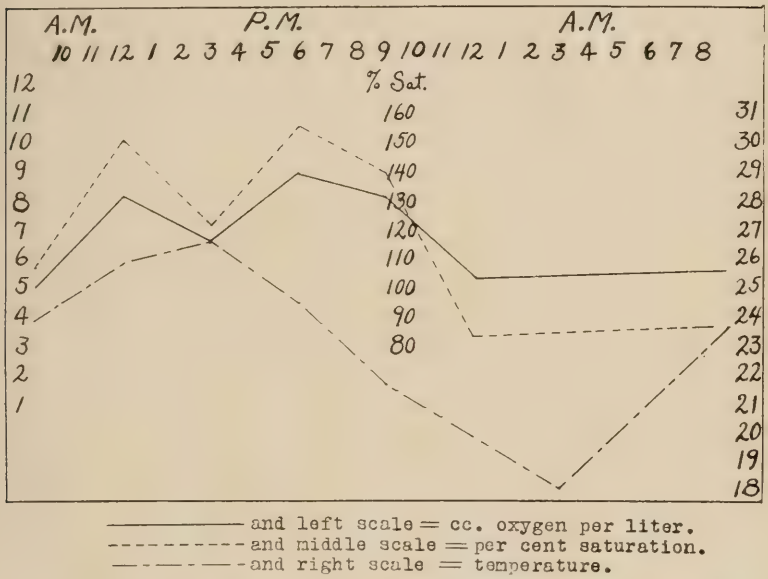


Fig. 1. Graph of records taken at Eagle Lake Littoral Station, August 9, 1922.

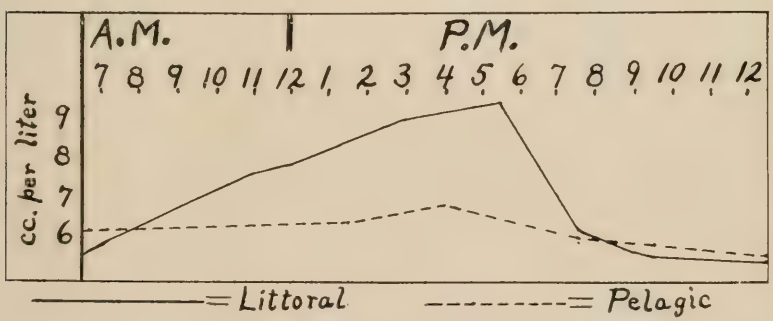


Fig. 2. Graph comparing the records taken at littoral and pelagic stations, respectively, August 9, 1922.

Series 3 is essentially like Curve 2 except that the maxima at both stations occurred at 3:30 p. m. At 6 p. m. a wind arose and from that time until 9 p. m. the curves approached each other.

It is evident from the data that an oxygen pulse occurs in the surface water of Eagle Lake on calm, clear days and that this pulse is

greater among the plants of the littoral than in the pelagic region of the lake.

Birge and Juday[1] report a diurnal oxygen pulse in Lake Mendota. They determined the amount of oxygen in the upper three meters of water just after 6 a. m. and a little before 5 p. m. They found a slight variation (.2 cc. per l.) at the surface, but a very decided pulse (1.8 cc. per l.) at the 1.5 m. level. Their observations were made September 20, 21, and 22.

[1] Birge, E. A., and Juday, C. 1911. The Inland Lakes of Wisconsin. The dissolved gases of the water. Bul. No. XXII, Wis. Geol. and Nat. Hist. Survey, p. 43.

A STUDY OF THE PRODUCTIVITY AND BREEDING HABITS OF THE BLUEGILL, LEPOMIS PALLIDUS (MITCH).[1]

LOWELL T. COGGESHALL, Indiana University.

The bluegill, *Lepomis pallidus* (Mitch.), one of the most common Centrarchids, has never been studied with regard to the number of young produced in a definite area under natural conditions. The method used was to count the entire number of nests in the lake and to collect and count the embryos in a few typical nests. The average per nest multiplied by the total number of nests gave the approximate number of young produced each year. An attempt was made to determine the total population of bluegills although this was very difficult because of the many varying factors concerned. This work was done during June, July, and August of 1921, 1922, and 1923, with a few observations during the months of March and October. The work was essentially the same for the three summers and was all done on Eagle (Winona) Lake.

Nests.—The nest of the bluegill is like that of the bass and several other Centrarchids. It is made by the male, which, by standing almost vertically over the nest and flipping the tail, brushes the lighter debris aside leaving shells, roots, or gravel for a solid bottom. The nature of the bottom regulates the depth and size of the nest; if the bottom of the nest is made up of thick roots it is always very shallow, never more than three or five centimeters in depth and more often just a clean place on the bottom. If the nest is located in marl it is much deeper with sloping sides, oftentimes 15 centimeters deep. The nests located in marl always have the bottom covered with dead shells and if the shells are thinly distributed the male makes a much deeper cavity in order to get enough shells to form the bottom of the nest. The nests average 28 inches across with some as wide as 36 inches.

The location of the nest is determined by the character of the bottom. As the nesting sites are observed from year to year it seems that the same places are selected again and again with only a little variation. Practically all of the nests are found at the edge of the two meter contour line where the water rapidly becomes deeper so that, when the bluegill is alarmed it may dart rapidly out to deeper water. Only a very few instances were noted where the nests were found at a depth of one half meter or less. They are found rarely in the Potamogetons unless these plants are unusually short and scattered. Nests were never found where the Potamogetons extend to a depth of 12 to 15 feet and are continuous with the spike rushes (*Scirpus americanus*) to the shore line. The bays in the lake are more densly populated than the shallower points.

Nests are almost always found in clusters, only three instances being noted where a single nest was found entirely apart from any

[1] This study was made at the suggestion and under the supervision of Dr. Will Scott, Director of the Indiana University Biological Station, Winona Lake, Indiana.

"Proc. Ind. Acad. Sci., vol. 33, 1923 (1924)."

other nest. This condition of clustered nests is due to the fact that the choice of one individual in the same general strip of favorable territory is naturally the choice of many others. Possibly there also exists a social instinct which causes the males to build nests in groups. These nests were very close together and as many as 120 have been counted in an area 150 feet in length and 15 feet wide.

In late spring and early summer it is very easy to count the nests since the water is very transparent although some of them were found as deep as seven or eight or even ten feet. For the summer of 1921

Fig. 1. Map of Eagle (Winona) Lake, showing the number and distribution of bluegill nests in 1921. The numbers indicate the location and number of nests in a group.

a total of 1,395 nests were counted, 1,874 in 1922, and 2,398 for the summer of 1923.

To determine the average number of embryos per nest, four typical nests were carefully collected and counted. The embryos were taken from the nest immediately after they were hatched when most of them still had the yolk sac attached. With the number of occupied nests and an average of the individuals per nest, the approximate number of young produced annually was determined. From the smaller nests the number was obtained by counting them out individually, in the larger nests approximately 1,500 would be counted out, the water filtered off and

their weight taken. The remainder of the nest would be drained and weighed in the same manner and the total number of young in the nest calculated.

From the four nests counted the following figures were obtained: 11,257; 30,374; 80,000; and 224,900, these representing the maximum and minimum sized nests. The average for these four nests is 86,631. According to this average, for the year 1923 in which 2,398 nests were counted, 207,751,138 young bluegills should have been hatched. If a single female laid in each nest this would mean that there are 2,400 mature egg-laying females in the lake. With an equal ratio between

Fig. 2. Same as figure 1, except that it is for 1922.

males and females there should be a total of 4,800 adult bluegills in the lake. This assumption of the equal ratio between males and females is used because in all hook and line catches as well as net catches the sexes were about equally divided. These figures are undoubtedly too low and there may be two plausible explanations. A number of females may lay in a single nest at one time for it is known that an individual male of the sunfish, *Eupomotis gibbosus*, has reared in a single nest two broods laid at different times by two females. While spawning the female darts rapidly to and fro over the nest making it impossible to keep her under observation all the time and to determine whether or not several females are laying in a single nest.

Reigard says that the relation between the sexes of *Eupomotis gibbosus* "may be regarded as promiscuous polygamy." This relationship is probably the same for the bluegill. As soon as the young bluegills have entirely absorbed their yolk sac they begin to leave the nest and within a few days all are gone, unguarded by either parent. Within a very few days the male will be seen hovering over another group of eggs in the same nest. This may happen two or three times during the same summer.

Not only do the females lay in the same nest successively but more than a single female's eggs are in a nest at the same time. This was

Fig. 3. Same as figure 1, except that it is for 1923.

determined in the following manner. A number of females with ripe ovaries were collected, the ovaries were removed and preserved, and from these ovaries one of average size was selected for the determination. The ovary was 3.3 cm. long and 2.3 cm. wide (from a fish 14 cm. in length). The eggs within it were large and fully developed. It was hardened in formalin and the eggs were readily teased apart for counting. In this ovary there were 11,257 eggs. Although there were some ovaries that contained twice as many eggs it hardly seems possible that the 224,900 embryos found in one nest were laid by a single female.

Assuming that the average number of eggs laid per female is 11,257 for the year 1923 there should be 18,467 egg-laying females in

Eagle Lake according to the number of young produced there that year. This would mean that the number of sexually mature fish is about 36,000 providing the numbers of males and females were equal.

At this point arises another question. If there are 18,000 males why have only 2,400 of them constructed nests? There are two possibilities. Either more than one male makes and guards a nest or a large percentage of the males are non-functional. The latter solution seems to be the more plausible of the two. All observations point to the fact that a single male guards the nest, when all of the males are driven off of a bed of nests the same male is always observed to return to the nest previously occupied. One instance where a single nest was observed over an extended period of time proved conclusively that the same male remained over a nest until the embryos had left. At first this male seemed extremely shy and at the first alarm he would dart away and remain some distance from the nest. After continued observations he became less alarmed and within a very short time he would remain quiet on the nest with the writer directly above him. If any attempt was made to disturb the male by reaching the hand down into the water he would dart at it furiously with no sign of alarm.

To determine the population at any one time or to determine the number that reach the adult stage is a very difficult problem due to the many factors involved. The mortality of these young fish is very high, that is from the time of hatching to the self-maintaining stage. The mortality from this stage to maturity is greatly reduced but is still high.

Enemies.— The worst enemy of the young bluegill is the illegal fisherman who fishes before the season opens or nets over the nests; or he who marks the beds and fishes the males off the first of the open season. The capture of a very few males leaves thousands of young fry to fall prey to the young bass, turtles and many other carnivorous forms.

Another serious enemy of the young bluegill is the spawning carp. The carp spawns at a time when the bluegill nesting season is at its height. In the middle of June, 1923, all the nests in one strip along the south shore of the lake were destroyed by the carp as they muddied up the water and uprooted the plants. In this particular instance over 40 nests were destroyed.

Summary.—The nest of *Lepomis pallidus* (Mitch.), the common bluegill, is a saucer-like excavation constructed by the male. Practically all of the nests are found inside of the two-meter contour line, which is the shelf of the lake where the water rapidly becomes deeper. These nests are never found in dense growths of aquatic plants and are always found in clusters.

The accompanying illustrations (figs. 1, 2, and 3) of Eagle Lake, which has an area of a little less than a square mile (556 acres), indicate the location and number of nests found in the years, 1921, 1922, and 1923, respectively. From four typical nests all the embryos were collected and counted, the average per nest was 86,631. From these counts it is estimated that approximately 207,000,000 bluegills were hatched out in Eagle Lake in 1923.

It has been determined that more than one female lays in a single nest, that is the relation between sexes is regarded as "promiscuous polygamy." From counts of eggs in the ovaries and the number of eggs sometimes found in nests, it is concluded that more than one female may lay eggs in a single nest. Repeated observations show that as soon as one brood leaves the nest, other females deposit their eggs in the empty nest.

It was estimated that there were 18,467 egg-laying females in Eagle Lake in 1923, this estimate being taken from the average number of eggs and the total number of young hatched. With an equal ratio there should be about an equal number of males. It is thought that a larger percentage of the males are non-functional since there were only 2,400 nests and probably 18,000 mature males.

Some of the serious enemies of the young bluegills are the illegal fishermen; also many carnivorous forms as young bass, darters and turtles. The spawning carp is another menace.

MEMBERS.[1]

Fellows.

Anderson, Flora Charlotte, 327 S. Henderson St., Bloomington.	1914[2]	1923[3]
Andrews, F. M., 901 E. Tenth St., Bloomington.	1896	1911
Arthur, Joseph C., 915 Columbia St., Lafayette.	Charter	1893
Badertscher, J. A., 312 Fess Ave., Bloomington.	1914	1917
Beede, Joshua S., 200 Seneca St., Bantesville, Okla.	1902	1906
Behrens, Charles A., 217 Lutz Ave., West Lafayette.	1916	1917
Bennett, Lee F., 309 S. Ninth St., Janesville, Wis.	1898	1916
Benton, Geo. W., c/o American Book Co., 100 Washington Square, New York, N. Y.	Charter	1896
Bigney, Andrew J., Evansville College, Evansville.	Charter	1897
Blanchard, William M., DePauw University, Greencastle	1909	1914
Blatchley, W. S., 1558 Park Ave., Indianapolis.	Charter	1893
Breeze, Fred J., State Normal, Muncie.	1898	1910
Bruner, Henry Lane, 324 Ritter Ave., Indianapolis.	1892	1899
Bryan, William Lowe, Indiana University, Bloomington.	1893	1914
Butler, Amos W., 52 Downey Ave., Irvington, Indianapolis.	Charter	1893
Carr, Ralph H., Purdue University, 27 N. Salisbury St., West Lafayette.	1914	1922
Cogshall, W. A., 423 S. Fess Ave., Bloomington.	1905	1906
Coulter, Stanley, 213 N. Ninth St., Lafayette.	Charter	1893
Culbertson, Glenn, Hanover College, Hanover.	1895	1899
Cumings, Edgar Roscoe, 327 E. Second St., Bloomington.	1900	1906
Deam, Charles C., Bluffton.	1900	1910
Dietz, Harry F., State Conservation Commission, Indianapolis.	1909	1922
Dryer, Charles R., 325 Grove St., Ft. Wayne.	Charter	1897
Dutcher, J. B., 1212 Atwater Ave., Bloomington	1907	1915
Eigenmann, Carl H., 630 Atwater Ave., Bloomington.	Charter	1893
Enders, Howard E., 249 Littleton St., West Lafayette.	1906	1912
Evans, Percy Norton, 302 Waldron St., West Lafayette.	1895	1901
Fisher, Martin L., 325 Vine St., West Lafayette.	1908	1919
Foley, Arthur L., 744 E. 3rd St., Bloomington.	1894	1897
Gardner, Max William, Purdue Agr. Exp. Sta., West Lafayette.	1919	1923
Hess, Walter N., Johns Hopkins University, Box 246, Baltimore, Md.	1917	1923
Hessler, Robert, 25 S. Bolton Ave., Indianapolis.	Charter	1899
Hufford, Mason E., 514 S. Sluss Ave., Bloomington.	1914	1916

[1] Every effort has been made to obtain the correct address of each member. In order to keep the mailing list correct, it is necessary that the secretary be informed of all changes of address. In accordance with the action of the Academy, members two years in arrears have been dropped from the roll.

[2] Date of election to Academy.

[3] Date of election to Fellowship.

Hurty, John E., 31 E. Eleventh St., Indianapolis	1902	1910
Hyde, Roscoe Raymond, 4101 Penhurst Ave., Baltimore, Md.	1909	1915
Jackson, Herbert S., Purdue Agr. Exp. Sta., West Lafayette.	1915	1919
Kern, Frank D., Dept. of Botany, State College, Pa.	1905	1912
Koch, Edward W., 24 High St., Buffalo, N. Y.	1914	1917
Logan, Wm. N., 924 Atwater Ave., Bloomington.	1916	1917
Mahin, Edward G., 27 Russell St., West Lafayette.	1916	1922
Markle, M. S., Earlham College, 528 National Ave., Richmond	1910	1919
McBeth, Wm. A., 1905 N. Eighth St., Terre Haute.	Charter	1904
McBride, Robert W., 1239 State Life Bldg., Indianapolis.	Charter	1916
Middleton, Arthur R., 705 Russell St., West Lafayette.	1906	1918
Moenkhaus, W. J., 320 S. Fess St., Bloomington.	1893	1901
Mottier, David M., 215 Forest Place, Bloomington.	Charter	1893
Naylor, Joseph P., Greencastle.	Charter	1903
Nieuwland, J. A., Notre Dame University, South Bend.	1908	1914
Payne, F., 620 Ballantine Road, Bloomington.	1913	1916
Ramsey, Rolla R., 615 E. Third St., Bloomington.	1904	1906
Rettger, Louis J., 31 Gilbert Ave., Terre Haute.	1893	1896
Rothrock, David A., 1000 Atwater Ave., Bloomington.	1898	1906
Scott, Will, 525 S. Park Ave., Bloomington.	1905	1914
Shannon, Charles W., 518 Lahoma Ave., Norma, Okla.	Charter	1912
Smith, Charles Marquis, 152 Sheetz St., West Lafayette	1910	1912
Stoltz, Charles, 311 W. Jefferson Blvd., South Bend.	1909	1919
Tucker, William Motier, 505 Ballantine Road, Bloomington.	1910	1923
VanHook, James M., 639 N. College Ave., Bloomington.	1909	1911
Wade, Frank Bertram, Shortridge High School, Indianapolis	1903	1914
Weatherwax, Paul, 416 S. Dunn St., Bloomington.	1913	1922
Williamson, E. B., Bluffton	1911	1914
Wright, John S., c/o Eli Lilly & Co., Indianapolis.	1893	1894
Yuncker, Truman G., 203 Wood St., Greencastle.	1919	1923

NON-RESIDENT MEMBERS AND FELLOWS.

Abbott, G. A., Grand Forks, N. D., Fellow ..... 1908[1]
Aldrich, John Merton, Washington, D. C., Fellow 1918
Brannon, Melvin A., Beloit, Wis.[2]
Burrage, Severance, Denver Colo., Fellow 1898
Campbell, D. H., Stanford, Cal.[2]
Clark, Howard Walton, U. S. Biol. Station, Fairport, Iowa 1900
Cook, Mel T., New Brunswick, N. J., Fellow 1902
Coulter, John M., University of Chicago, Ill., Fellow 1893
Davis, B. M., Oxford, Ohio.[2]
Evermann, Barton Warren, Golden Gate Park, San Francisco, Cal.[2]
Goss, William Freeman M., 61 Broadway, N. Y., Fellow 1893

[1] Date of Membership or Fellowship.
[2] Elected previous to 1891.

Greene, Charles Wilson, 814 Virginia Ave., Columbia, Mo.[5]
Hargitt, Charles W., 909 Walnut St., Syracuse, N. Y.[5]
Hay, Oliver Perry, U.S. National Museum, Washington, D.C. ...1893
Jordan, David Starr, Stanford, Cal. 1893
Kingsley, John S., Urbana, Ill.[5]
Knipp, Charles T., 915 W. Nevada St., Urbana, Ill. 1894
MacDougal, Daniel Trembly, Tucson, Ariz.[5]
McMullen, Lynn Banks, 641 Euclid Ave., Valley City, N. D. 1900
Marsters, Vernon, F., Kansas City, Mo., c/o C. N. Gould, Fellow..1893
Miller, John Anthony, Swarthmore, Pa., Fellow 1904
Moore, George T., Missouri Botanical Garden, St. Louis, Mo. 1909
Noyes, William Albert, Urbana, Ill., Fellow 1893
Ransom, James H., Detroit, Mich., Fellow 1902
Springer, Alfred, 312 E. Second St., Cincinnati, Ohio.
Swain, Joseph, Swarthmore, Pa., Fellow.....1898
Von Kleinsmid, R. B., Univ. of So. California, Los Angeles, Cal....1920
Waldo, Clarence A., Fellow (address not known) 1893
Wiley, Harvey W., Woodward Bldg., Washington, D.C. 1895
Zeleny, Chas., 1003 W. Illinois St., Urbana, Ill. 1904

Active Members.

Acre, Harlan Q., Gordon, Nebr. .....1918[6]
Adams, Esther, 5244 Burgess St., Indianapolis 1923
Adams, James Edward, 419 W. Wood St., West Lafayette 1921
Adams, William B., 431 S. College Ave., Bloomington 1919
Addington, Archie, 801 Atwater Ave., Bloomington 1921
Allee, W. R., 221 E. Fourth St., Bloomington 1922
Allen, William Ray, University of Kentucky, Lexington, Ky. 1912
Anderegg, Frederick O., 825 N. Main St., West Lafayette 1918
Anthony, Harvey Mitchell, Anthony Bldg., Muncie 1923
Armington, John H., U.S. Weather Bureau, Indianapolis 1921
Atkinson, F. C., 2534 Broadway, Indianapolis 1914
Auble, Robert N., 409 N. Wolcott St., Indianapolis 1922
Ayres, Agnes W., 1003 State St., West Lafayette 1923
Baker, Lora M., 408 S. Grant St., Bloomington 1920
Baker, Wm. F., Box 586, Carmel 1914
Balcom, Stephen F., 2634 Birchwood Ave., Indianapolis 1920
Baldwin, Ira L., 422 Russell St., West Lafayette 1919
Barnett, Horace L., Box 509, Portland 1922
Barnhill, Dr. J. F., Indiana Univ. School of Medicine, Indianapolis..1916
Barr, Harry L., Buckley, Ill. 1911
Barrett, Edward, State Geologist, Indianapolis 1911
Bartle, Glenn Gardner, 218 W. Market St., New Albany 1923
Beals, Colonzo, 103 Russell St., Hammond 1915
Beck, Carol Harriet, R. R. J, Lafayette 1923
Becktel, Albert R., 209 W. College St., Crawfordsville.....1920
Beecher, Alva, 1010 E. Pike St., Crawfordsville 1922
Beeson, K. E., 427 State St., West Lafayette.....1922

[6] Date of membership in the Academy.

Begeman, Hilda, 24 Linden St., Wellesley, Mass. 1919
Bell, Alma Marie, 334 S. Dunn St., Bloomington 1922
Berg, George F., Jr., 926 E. 49th St., Indianapolis 1922
Berteling, Dr. J. B., 228 W. Colfax Ave., South Bend 1914
Black, Homer F., 118 E. 26th St., Chicago, Ill. 1916
Blaydes, Glenn William, Roachdale 1923
Bloye, Amy Irene, 115 E. Columbia St., West Lafayette 1923
Bockstahler, Lester, 101 Haven House, Evanston, Ill. 1920
Bodine, Mrs. Emma, 4 Mills Place, Crawfordsville 1921
Bolen, Homer R., 314 S. Grant St., Bloomington 1922
Bond, Dr. Charles S., 112 N. Tenth St., Richmond 1900
Bond, Dr. George S., 2104 N. New Jersey St., Indianapolis 1916
Boots, Edwin B., 125 N. Sixth St., West Terre Haute 1922
Bourke, Adolphus A., 2304 Liberty Ave., Terre Haute 1909
Brandt, Helen Rowan, 2234 High St., Logansport 1923
Brewer, P. H., 145 E. Oak St., West Lafayette 1921
Brock, James E., 710 Atwater St., Bloomington 1922
Brosey, Charles L., Technical High School, Indianapolis 1922
Brossmann, Charles, 1503 Merchants Bank Bldg., Indianapolis ...1909
Bruce, Edwin M., 2108 N. Tenth St., Terre Haute 1918
Burton, Everett T., 3100 Broadway, New York, N. Y. 1920
Bushnell, T. M., Purdue Agr. Exp. Sta., Lafayette 1922
Bybee, Halbert P., University Station, Austin Texas 1912
Byers, Cecil W., Box 332, University Station, Grand Forks, N. D...1919
Cain, Stanley A., 30 N. Holmes St., Indianapolis 1921
Campbell, Elmer G., 220 Sylvia St., West Lafayette 1919
Campbell, Marion S., 29 N. Hawthorne Lane, Indianapolis 1921
Canis, Edward N., Route A-2, Box 372-A, Indianapolis 1909
Caparo, Jose Angel, Notre Dame University, South Bend.....1914
Carter, Edgar B., 4555 Central Ave., Indianapolis.....1918
Cassady, Emil V., Mitchell 1920
Cavins, Alexander, 1232 N. Alabama St., Indianapolis 1920
Chansler, Elias J., Bicknell 1895
Chapman, Edgar K., 506 S. Grant St., Crawfordsville 1911
Chitty, Ethel, 1905 W. Main St., Muncie 1922
Christie, George Irving, 607 University St., West Lafayette 1923
Christy, O. B., Indiana State Normal, Muncie 1919
Clark, Jediah H., 126 E. Fourth St., Connersville 1909
Clay, Mrs. Celia, 320 N. State St., Kendallville.....1922
Clement, Mrs. Wilbur, R. F. D., West Point 1908
Cleveland, Clarence R., Purdue Agr. Exp. Sta., Lafayette 1921
Cloves, G. H. A., Eli Lilly & Co., Indianapolis 1920
Coffel, Hal Herbert, Pennville 1923
Coggeshall, Lowell T., Biology Hall, Bloomington 1921
Conner, S. D., 204 S. Ninth St., Lafayette 1912
Cook, Rolla V., Bethany, West Va. 1921
Coryell, Noble H., Columbia University, New York, N. Y. 1914
Cottman, Evans W., Lanier Place, Madison 1921
Cox, C. F., 528 N. Oxford St., Indianapolis 1922
Crockett, W. P., 419 W. 49th St., Indianapolis 1919

Crozier, Alice M., 312 Kenmore Rd., Indianapolis 1921
Cummins, John A., Ind. Central College, Indianapolis 1923
Curtis, Lila C., Arbutus Flat D, Bloomington 1920
Danglade, Ernest, Vevay 1920
Davis, Charles, 217 Sylvia St., West Lafayette 1922
Davis, Edna E., Indiana State Normal, Muncie 1923
Davis, Harold Thayer, 613 S. Henderson St., Bloomington 1923
Davis, Hugh L., 423 Vine St., West Lafayette 1921
Davis, John J., Purdue University, Lafayette 1920
Davis, Ward B., Botany Bldg., Univ. of Chicago, Chicago, Ill. ...1921
Dean, John C., University Club, Indianapolis 1914
DeForest, Howard. Indianapolis Normal School, Indianapolis ...1921
Demaree, Delzie, Hendrix College, Conway, Ark. 1920
Deppe, C. A., Franklin 1911
Derby, Ira Harris, 5460 University Ave., Indianapolis 1920
Deuker, Henry W., Jr., State Board of Health, State House, Indianapolis 1921
Dietz, Emil, 334 Congress Ave., Indianapolis 1921
Diggs, John C., 308 N. Gladstone Ave., Indianapolis 1920
Dilts, Charles D., 3121 Fairfield Ave., Ft. Wayne 1920
Doan, Martha, Earlham College, Richmond 1896
Doan, Richard L., Reed College, Portland, Ore. 1922
Dolan, Joseph P., Syracuse 1895
Domroese, Fred C., 815 W. Main St., Crawfordsville 1920
Donahue, Joseph N., Columbia University, Portland, Ore. 1920
Douglass, Benjamin W., Trevlac 1916
Downhour, Elizabeth, 411 N. Delaware S., Indianapolis 1915
Dugan, Elizabeth, 312 N. Ritter Ave., Indianapolis 1922
Dunham, David H., 429 Main St., West Lafayette 1920
Earp, Samuel E., 634 Occidental Bldg., Indianapolis 1909
East, Mrs. Pearl W., Gilman, Iowa 1920
Eaton, Dunwald L., Indiana Central College, Indianapolis 1922
Edmondson, Clarence E., 822 Atwater Ave., Bloomington 1912
Eisenhard, Geo. B., Culver Military Academy, Culver 1921
Eisenhard, Mrs. Geo. B., Culver 1921
Eldred, Frank R., 3325 Kenwood Ave., Indianapolis 1918
Elkin, Sarah K., 612 Harvey Ave., West Lafayette 1921
Elliott, Edward Charles, 515 S. Seventh St., Lafayette 1923
Emerson, Dr. Charles P., 602 Hume-Mansur Bldg., Indianapolis ...1915
Estabrook, Arthur H., Board of State Charities, Indianapolis ...1916
Etter, Austin, 41 Zeno St., Grand Rapids, Mich. 1920
Evans, Samuel G., 1452 Upper Second St., Evansville 1891
Fadley, Leon, Indiana State Normal, Muncie 1923
Feldman, Horace W., 138 Chauncey Ave., West Lafayette 1920
Ferguson, Luther S., Williams 1920
Finley, George W., 18 E. National Ave., Brazil 1923
Finster, Ethel B., Indiana State Normal, Muncie 1923
Flemion, Florence Dorothy, 301 E. Kirkwood Ave., Bloomington ...1923
Foresman, George K., 110 S. Ninth St., Lafayette 1914
Franklin, Fred F., Washington 1921

Frazier, Jesse M., Indiana State Normal, Muncie 1923
Frey, Franklin E., 222 Ohmer Ave., Indianapolis 1923
Friesner, Mrs. Gladys M., 5360 Julian Ave., Indianapolis 1923
Friesner, Ray C., Butler College, Indianapolis 1919
Froning, Henry B., 415 Pokagon St., South Bend 1920
Fugate, Mary, 2525 Park Ave., Indianapolis 1920
Fuller, F. D., 3021 College Ave., Bryan, Texas 1910
Funk, Dr. Austin, 404 Spring St., Jeffersonville 1895
Gage, George R., 112 Bloomington St., Greencastle 1923
Galloway, Jesse J., Geology Dept., Columbia Univ., New York, N. Y. 1910
Gamble, Mary Edith, 120 Chauncey Ave., West Lafayette 1923
Gantz, Richard A., State Normal School, Muncie 1920
Garrard, Herbert Leland, 216 Waldron St., West Lafayette 1923
Garver, Frederick R., 510 E. Fifth St., Bloomington 1921
Gatch, Willis D., 605 Hume-Mansur Bldg., Indianapolis 1915
Gates, Florence A., 3435 Detroit Ave., Toledo, Ohio 1909
Gayler, Dona G., 200 N. Sixth St., Terre Haute 1920
Gidley, William F., 276 Littleton St., West Lafayette 1914
Gillum, Robert G., Indiana State Normal, Terre Haute 1913
Gingery, Walter G., Shortridge High School, Indianapolis 1918
Goldsmith, William M., Southwestern College, Winfield, Kans. ...1914
Goodale, Charles DeLoss, 221 Waldron St., West Lafayette 1923
Graham, Frank V., Indiana State Normal, Muncie 1920
Graves, Benjamin H., 604 E. Market St., Crawfordsville 1920
Greene, Frank C., 1434 Cincinnati Ave., Tulsa, Okla. 1908
Gregory, Charles T., 1022 First St., West Lafayette 1922
Guernsey, E. Y., 120½ W. 46th St., Los Angeles, Cal. 1921
Guthrie, W. A., 10 E. Market St., Indianapolis 1920
Hadley, Joel W., 4445 Guilford Ave., Indianapolis 1919
Hagey, G. L., 219 Wiggins St., West Lafayette 1920
Hammond, Alyce L., Glendale Park, Hammond 1923
Hanna, U. S., 828 Atwater Ave., Bloomington 1914
Hansen, Albert A., Purdue Agr. Exp. Sta., Lafayette 1921
Hansford, Hazel I., Southeastern Hosp. for Insane, North Madison. 1916
Happ, William, South Bend 1914
Harding, Charles F., 503 University St., West Lafayette 1908
Harding, Wilbur T., 128 Andrew Place, West Lafayette 1923
Hardy, Eugene H., 1230 S. Keystone Ave., Indianapolis 1920
Harger, Rolla Neil, 3913 Kenwood Ave., Indianapolis 1923
Hargitt, Thomas F., 412 Smith Ave, Bloomington.....1923
Hargrave, Ellis, Frankfort 1923
Harmon, Paul M., 311 E. Smith Ave., Bloomington 1915
Harvin, Glenn Beckham, 108 Waldron St., West Lafayette 1923
Hassenzahl, Elizabeth, 424 Vine St., West Lafayette 1921
Hayner, Clark Ross, 277½ Littleton St., West Lafayette 1923
Hedebol, Frederick C. N., 809 W. Grand Blvd., Springfield, Ill. ...1920
Heimburger, Harry V., Hamline Ave., St. Paul, Minn. 1912
Heimlich, Louis F., 495 Littleton St., West Lafayette 1914

Hendricks, Victor K., 764 Illinois Merchants Bank Bldg., Chicago, Ill. 1900
Hill, William J., 322 Kirkwood Ave., Bloomington 1923
Hills, Donald H., 2127 Talbott Ave., Indianapolis 1922
Hinman, Jack J., University of Iowa, Iowa City, Iowa 1912
Hoffer, Geo. N., 434 Littleton St., West Lafayette 1922
Hoffman, A. C., 576 Lowell Ave., Indianapolis 1922
Hoffman, G. L., Western Pennsylvania Hospital, Pittsburgh, Pa. ..1911
Hole, Allen D., 615 National Road West, Richmond 1901
Howick, Howard, Indiana State Normal, Muncie 1921
Howlett, Berton A., 503 Elm St., Valparaiso 1919
Huber, Leonard L., Hanover College, Hanover 1915
Hufferd, Ralph, Greencastle 1920
Hull, Julia, St. Anne, Ill. 1919
Hunt, Raymond S., 508 E. Third St., Bloomington 1923
Hutchinson, Emory, Norman Station 1915
Hutton, Joseph G., State College, Brookings, S. D. 1911
Hyslop, George H., 143 Twenty-second St., Long Island, N. Y. ...1914
Irving, Thomas P., Notre Dame University, South Bend 1914
Jackson, James W., Central High School, Chattanooga, Tenn. ...1918
James, Charles M., 443 Wood St., West Lafayette 1921
James, Evalyn G., 144 Butler Ave., Indianapolis 1919
Jensen, Howard E., 360 Downey Ave., Indianapolis 1921
Johnston, Harriet DeGraff, 76 Layman Ave., Indianapolis 1923
Jordan, Charles Bernard, 409 Russell St., West Lafayette 1914
Kaczmarek, Regidius M., Box 54, Notre Dame Univ., South Bend..1914
Kaley, Leona M., 523 N. Beville St., Indianapolis 1923
Kantor, Jacob R., 645 N. Walnut St., Bloomington 1920
Katterjohn, Mable C., Lynnville 1920
Kellogg, Mary, 124 Marstellar St., West Lafayette 1923
Kendall, Mrs. Grace Dean, Evansville 1922
Kendrick, James B., Purdue Agr. Exp. Sta., Lafayette 1921
Kennedy, Clarence H., Ohio State Univ., Columbus, Ohio..... 1922
Kennedy, Glenn DeFore, 266 Littleton St., West Lafayette 1923
Kiester, Jackson A., 300 S. Green St., Crawfordsville 1922
Kinnet, Russell, Milroy 1923
Kinsey, Alfred C., 615 S. Park Ave., Bloomington 1920
Kiplinger, Walter C., 2234 Park Ave., Indianapolis 1922
Knecht, Christian, 207 N. Dunn St., Bloomington..... 1922
Knotts, Armanis, F., Anglis, Fla. 1917
Kohl, Edwin J., 218 Fowler Ave., West Lafayette 1917
Lanham, Miss Bess, 610 E. Wabash Ave., Crawfordsville 1922
Larrimer, Walter H., Box 95, West Lafayette 1921
Leaming, Eleanor Patton, 825 S. Ninth St., West Lafayette 1923
Lieber, Richard, State House, Indianapolis 1919
Liston, Jesse G., R. F. D. 2, Lewis 1916
Loew, Fred A., Huntington College, Huntington 1923
Loughridge, Gasper Arthur, 407 S. Grant St., Bloomington 1923
Ludwig, C. A., Clemson College, S. C. 1911

Ludy, Llewellyn V., 600 Russell St., West Lafayette 1908
Luten, Daniel B., 1056 Consolidated Bldg., Indianapolis 1918
Lyon, Marcus Ward, Jr., 214 Laporte Ave., South Bend.....1922
Mains, E. B., 212 S. Grant St., West Lafayette 1916
Malott, Burton J., Technical High School, Indianapolis 1916
Malott, Clyde A., 521 E. Second St., Bloomington 1914
Malott, Ruth Boyd, 629 Carlisle Place, Indianapolis 1922
Mannfeld, George N., 1235 Central Ave., Indianapolis 1922
Martin, Ersie S., 134 N. Drexel St., Indianapolis 1922
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis 1922
Mason, Thomas E., 103 Waldron St., West Lafayette 1905
McAvoy, Miss Blanche, 1621 N. Jackson St., Muncie 1921
McCarty, Morris, High School, Montmorenci 1917
McDonald, Clinton C., 415 S. Dunn St., Bloomington 1922
McDonald, Doloris, 422 Mechanic St., Shelbyville 1921
McEachron, Karl B., 52 Stratford Ave., Pittsfield, Mass. 1921
McGavran, Edward, Downey Ave., Indianapolis 1921
McWilliams, Thelma, 126 Lutz Ave., West Lafayette 1923
March, Verna Louise, 124 Pierce St., West Lafayette 1923
Mellon, M. G., 403 Russell St., West Lafayette 1921
Michael, Lyle Jordan, Indiana Central College, Indianapolis 1922
Miller, Fred A., Eli Lilly Co., Greenfield 1908
Miller, John W., 115 E. Columbia St., West Lafayette 1919
Molony, Rev. William Hayes, Notre Dame University, South Bend..1922
Montgomery, Basil E., Poseyville 1922
Montgomery, H. T., 208 Dean Bldg., South Bend 1898
Moore, John Irwin, Owensville 1922
Moore, Kenneth W., 125 Downey Ave., Indianapolis 1921
Moorhead, John G., 423 Salisbury St., West Lafayette 1922
Morgan, Frank W., 8213 Spruce St. New Orleans, La. 1920
Morgan, Lawrence O., 205 Dryden Road, Ithaca, N. Y. 1923
Morgan, Will, University Heights, Indianapolis.....1920
Morrison, Harold, Bureau of Entomology, Washington, D. C.....1910
Morrison, Louis A., care Edward Morrison, Mich. Agr. Coll., East Lansing, Mich. 1917
Mount, Harry W., 1012 Lexington Ave., Indianapolis 1923
Muldoon, Hugh C., 503 Main St., Valparaiso 1920
Mullendore, Miss Naomi, Franklin 1922
Munro, George W., 202 Waldron St., West Lafayette 1917
Myers, B. D., 321 N. Washington St., Bloomington 1911
Neff, Joseph Edgar, 132 S. Scott St., South Bend 1923
Nelson, Ralph E., 232 Littleton St., West Lafayette 1914
Nester, Henry George, 2832 N. Capitol Ave., Indianapolis 1923
Newton, Roy C., 434 N. Grant St., West Lafayette.....1923
Nicholson, Thomas E., 519 N. Fess Ave., Bloomington.....1918
Niles, Edward H., 4450 Guilford Ave., Indianapolis 1920
Noble, Willis Bernard, Box 95, West Lafayette 1922
Noyes, Harry A., New Rochelle Research Laboratory, New Rochelle, N. Y. 1916

Oberholser, Harry C.. 2805 Eighteenth St., N. W., Washington, D. C. 1914
O'Neal, Claude E., 95 Oak Hill Ave., Delaware, Ohio..... 1912
Orahood, Harold, Union Mills 1914
Orton, Clayton R., State College, Pa. 1910
Osbun, Clifford Leroy, 201 Russell St., West Lafayette 1922
Otten, Ralph Edward, R. R. 2, Rossville..... 1923
Painter, Henry R., Box 95, West Lafayette 1921
Parfitt, Elliott H., 318 N. Grant St., West Lafayette 1923
Payne, Mary G., 303 S. Downey Ave., Indianapolis 1922
Pearson, George B., Box 95, West Lafayette..... 1921
Pearson, Nathan E., Biology Hall, Indiana University, Bloomington. 1922
Peffer, Harry C., 1022 Seventh St., West Lafayette 1914
Petry, Edward J., 625 Twelfth Ave., Brookings, S. D. 1911
Phillips, George R., 234 E. Pratt St., Indianapolis 1923
Pickett, Fermen L., Station 178, Pullman College, Washington.... 1909
Pinkerton, Earl, Box 447, Walters, Okla. 1916
Pitkin, Edward M., 309 Washington St., Martinsville..... 1922
Poe, Doris J., 1726 E. Washington St., Indianapolis 1923
Pollard, Cash B., 419 W. Wood St., West Lafayette 1921
Porter, Bennet A., 10 W. Sycamore St., Vincennes..... 1923
Porter, Charley Lyman, 828 N. Main St., West Lafayette..... 1923
Prentice, Burr N., 400 Russell St., West Lafayette 1915
Price, Walter A., 123 Sheetz St., West Lafayette 1919
Priest, Bernice, W. Sixth St., Marion 1923
Proulx, Edward G., 111 Waldron St., West Lafayette 1918
Raab, Albert L., 1351 Consolidated Bldg., Indianapolis..... 1921
Rawles, William P., 924 E. Third St., Bloomington..... 1920
Reagan, Albert B., Cornfields, Ganado, Ariz. 1902
Records, Ralph L., Edinburg 1920
Reed, Harry J., Purdue Agr. Exp. Sta., Lafayette 1923
Reed, Dr. William C., 728 E. Third St., Bloomington 1923
Reeves, John R., Indiana University, Geology Dept., Bloomington.. 1920
Reinhard, Herbert F., Room 152, State House, Indianapolis..... 1921
Richards, Dr. and Mrs. Aute, University of Oklahoma, Norman, Okla. 1916
Ricketts, Helen E., 3215 Olney St., Indianapolis..... 1923
Ridway, Robert, 1030 S. Morgan St., Olney, Ill. 1920
Riecken, William E., 803 E. Fourth St., Mount Vernon..... 1923
Rifenburgh, S. A., 130 S. Grant St., West Lafayette 1916
Riley, Katherine, 56 Whittier Place, Indianapolis..... 1916
Roark, Louis, Box 1266, Okmulgee, Okla. 1917
Roberts, Chester R., 901 E. Jefferson St., Franklin..... 1919
Roberts, Harry John, Route A, Lafayette..... 1922
Robertson, Leo Fred, Monterey 1923
Robertson, Ray B., 702 Evergreen St., West Lafayette 1922
Rogers, Ruth Anna, 533 N. Grant St., West Lafayette 1923
Senour, Frank C., 323 N. Grant St., Bloomington 1922
Sheak, Wm. H., 154 N. 21st St., Philadelphia, Pa. 1916

Sherman, George W., 8 Murdock Flats, West Lafayette 1918
Shirk, John C., 1100 Main St., Brookville.....1923
Shlensky, Morris Ralph, 450 E. Sibley St., Hammond.....1923
Shonle, Horace A., Eli Lily & Co., Indianapolis.....1919
Showalter, Ralph W., Eli Lilly & Co., Indianapolis.....1915
Shrock, Robert R., Bennett's Switch 1923
Silvey, Oscar W., College Station, Texas 1909
Smith, Charles Piper, 354 S. Tenth St., San Jose, Cal. 1903
Smith, Elmer Gillam, 101 E. Columbia St., West Lafayette.....1923
Smith, Ernest R., 628 E. Walnut St., Greencastle 1921
Smith, Geraldine Frances, 421 University St., West Lafayette.....1923
Smith, John C., Physics Department, Franklin College, Franklin...1919
Smith, Lee T., 522 N. Washington St., Bloomington 1922
Smith, Paul R, Univ. of Pennsylvania, Philadelphia, Pa.....1920
Snodgrass, Robert E., Bureau of Entomology, Washington, D. C.....1917
Spangler, Iva, Indiana State Normal, Muncie 1923
Spitzer, George, 1000 Seventh St., West Lafayette 1909
Spong, Philip, 3873 E. Washington St., Indianapolis.....1916
Stacy, Allan R., 1555 Ashland Ave., Indianapolis.....1921
Stirrett, George M., 521 State St., West Lafayette 1922
Stone, Ralph B., 307 Russell St., West Lafayette 1914
Strickler, Alvin, Evansville College, Evansville 1922
Sulzer, Elmer G., Madison 1918
Suter, E. M., 3025 S. Clinton St., Ft. Wayne 1920
Switzer, J. Elmer, 1001 Atwater Ave., Bloomington 1923
Tasker, Roy C., 707 S. College Ave., Greencastle 1922
Tatlock, Myron W., Shortridge High School, Indianapolis.....1918
Taylor, George O., 2103 S. 48th St., Cicero, Ill. 1922
Telfer, Margaret, 403 W. Fifth St., Bloomington.....1921
Terry, Dr. Oliver P., 215 Sheetz St., West Lafayette 1914
Test, Louis A., 511 Russell St., West Lafayette 1918
Tetrault, Philip A., 607 University St., West Lafayette 1914
Tevis, Emma L., 122 W. Eighteenth St., Indianapolis 1916
Thompson, Clem O., Earlham College, Richmond 1911
Thompson, James T., 334 Lafayette Ave., Lebanon 1920
Thornburn, A. D., 42 E. 37th St., Indianapolis.....1909
Tharsher, Mrs. John R., Apt. 1, 3805 N. Delaware St., Indianapolis.1921
Toole, Eben Henry, Bureau of Plant Industry, Washington, D. C...1917
Treat, Frank M., Atwater Ave., Bloomington 1920
Troop, James, 123 Sheetz St., West Lafayette 1914
Turley, Harold E., 1135 Fullerton Ave., Chicago, Ill. 1921
Turner, B. B., 1017 Park Ave., Indianapolis 1916
Turner, William P., 222 Lutz Ave., West Lafayette 1908
Twitty, Victor, 411 E. 50th St., Indianapolis 1921
Van Nuys, W. C., Box 34, Newcastle 1914
Vernon, Sarah Evelyn, Royal Centre 1923
Visher, Stephen S., 817 E. Second St., Bloomington 1919
Voorhees, Herbert S., 804 Wildwood Ave., Ft. Wayne.....1896
Wagener, Edward F., 1138 Oxford St., Indianapolis.....1923

Wallace, Frank N., Dept. of Entomology, State House, Indianapolis.1920
Ward, Mary Mallory, 405 E. William St., Kendallville.....1922
Watson, Ivan Dale, 417 Waldron St., West Lafayette.....1923
Weems, Mason L., 102 Greenfield Ave., Valparaiso 1909
Wenninger, Rev. Francis J., Notre Dame University, South Bend.1920
Wiancko, Alfred T., 230 S. Ninth St., Lafayette.....1909
Wildman, Ernest A., Earlham College, Richmond 1918
Wiley, Ralph B., 777 Russell St., West Lafayette 1914
Wilhite, Miss Ida B., 401 N. Illinois St., Indianapolis 1921
Wilkinson, Paul D., 1636 S. Fourth St., Terre Haute 1921
Williams, A. A., Valparaiso 1916
Williamson, Jesse H., Bluffton 1921
Wilson, Arthur J., 901 W. Wabash St., Crawfordsville 1920
Wilson, E. R., 2830 E. Vermont St., Indianapolis 1922
Wilson, Mrs. Etta, 9077 Clarendon Ave., Detroit, Mich. 1915
Wilson, Geo. B., 427 State St., West Lafayette 1921
Wilson, Ira T., Heidelberg College, Tiffin, Ohio 1919
Wilson, Judson D., 429 E. Seventh St., Bloomington 1923
Winkenhofer, Walter, Huntingburg 1920
Witmer, Samuel W., 1405 Ninth St., Goshen 1921
Wolfe, Harold E., 314 N. Washington St., Bloomington.....1920
Wood, Harry W., 1218 Victor Ave., Chicago, Ill. 1912
Woodruff, Albert E., University of Chicago, Chicago, Ill. 1921
Young, Gilbert A., 739 Owen St., Lafayette 1908
Young, Herman H., 446 E. Second St., Bloomington 1922
Young, Paul A., 605 W. University Ave., Urbana, Ill. 1920
Zebrowski, George, Villa Nova College, Villa Nova, Pa.....1920
Zehring, William A., 303 Russell St., West Lafayette 1907
Zerfas, Leon G., 706 Huntington Ave., Boston, Mass. 1921
Zierer, Clifford M., Batesville 1922
Zumstein, Reginald Bernard, 810 N. Sixth St., Lafayette.....1923

Summary of Membership.

Fellows	63
Members, Active	396
Members and Fellows, Non-resident	30
Total	489

INDEX

PAGE

A Case of Stream Piracy near Greencastle, Indiana 73
A Change of Drainage of Raccoon Creek, Parke county 63
A Plea Against Over-Standardization in Scientific Education 47
Aims of the Indiana Academy of Science 5
Allium vineale, Seed Production in Indiana 213
Anderegg, F. O. 93
Andrews, F. M. 259, 264, 265, 266
Bacteriology and its Practical Significance 35
Baldwin, I. L. 269
Bartle, Glenn G. 63
Behrens, Charles A. 35
Blanchard, W. M. 103
Bluegill (Lepomis pallidus), Productivity and Breeding Habits 315
Bolen, Homer R. 307
Boric Acid, The Electrometric Titration of 85
Brookville and its Contribution to the State 19
Bushnell, T. M. 69
Butler, Amos W. 14
Cancer in Indiana 55
Coggeshall, Lowell T. 315
Culture Methods in the Production of Polyembryony in certain Ferns (Polypodiaceae) 239
Culture Methods in Rust Investigations 241
Davis, J. J. 287
Deam, Chas. C. 221
Death Rate in Indiana 55
Development of Soil Survey 69
Dietz, Harry F. 299
Diurnal Oxygen Pulse in Eagle Lake 311
Drainage of Raccoon Creek, Parke County 63
Dunes Region of Porter County, Some Soil and Water Reactions 281
Early History of the Indiana Academy of Science 14
Earwigs, Function of their Forceps 303
Education, A Plea Against Over-Standardization 47
Eisenhour, B. 115
Electrometric Titration of Boric Acid 85
Entomology, Relation to Human Life and the Sciences 287
Erlanson, Eileen W. 123
Familiarizing Students with the Gram-Molecular Volume of Gases .. 103
Fishes, Relation of Size to Age 307
Foley, Arthur L. 105, 115
Forceps of Earwigs 303
Fungi of Indiana 233

PAGE
Gardner, Max W. 163, 202
Gases, Effect of Silent Electric Discharge 77
Geographic Variations in Indiana in Typhoid, Tuberculosis, Cancer and in Total Deaths 55
George, R. H. 77
Gram-Molecular Volume of Gases 103
Grasses, Notes on 223
Grimes Collection of Plants from Putnam County 123
Hansen, Albert A. 213, 214, 216
Heimlich, Louis F. 225
History of the Indiana Academy of Science 14
Indiana Academy of Science, Aims and Purposes 5
Indiana Academy of Science, Birthplace 10
Indiana Academy of Science, Committees 7
Indiana Academy of Science, Early History 14
Indiana Academy of Science, Minutes 11, 23
Indiana Academy of Science, Officers 7
Indiana Academy of Science, Past Officers 9
Indiana Fungi 233
Indiana Mammals, New Records 284
Indiana Plants 221
Indiana Plants, Chiefly from Putnam County 123
Indiana Plant Diseases 163, 201
Indiana Termites 299
Indiana Weeds 214, 216
Insects, Relation to Human Life and the Sciences 287
Lindsey, R. O. 269
List of Members 321
Locomotive Whistles 105
Logarithm of Logarithmic Decrement 121
Lyon, Jr., Marcus Ward 281, 284
Mahin, E. G. 47
Mains, E. B. 241
Mammals, New Records in Indiana 284
Mellon, M. G. 85
Members, List 321
Midsummer Growth 264
Minutes of Spring Meeting 11
Minutes of Winter Meeting 23
Morgan, W. P. 303
Morris, V. N. 85
Mottier, David M. 239
New Records of Indiana Mammals 284
Nichter, W. J. 269
Nitrate Studies on Purdue Rotation Field No. 6 269
Notes on Grasses 223
Notes of Greenhouse Culture Methods in Rust Investigations 241
Notes on the Function of the Forceps of Earwigs 303
Notes on the Termites of Indiana, II 299

PAGE
Oplinger, K. A. 77
Oxygen Pulse in Eagle (Winona) Lake 311
Parke County, A Change of Drainage of Raccoon Creek 63
Piracy of Streams near Greencastle, Indiana 73
Plant Diseases, 1921 163
Plant Diseases, 1922 202
Plants New or Rare in Indiana, XII 221
Plants of Putnam County 123
Plants of White County, VI 225
Pollen Studies 265
Polyembryony in Certain Ferns, Culture Methods 239
Power Required to Drive Spoke and Disk Wheels and Pulleys 115
President's Address 35
Productivity and Breeding Habits of the Bluegill 315
Program 23
Properties of Water 93
Protoplasmic Streaming 266
Pulleys, Power Required to Drive 115
Purposes of the Indiana Academy of Science 5
Putnam County Plants 123
Raccoon Creek, A Change of Drainage 63
Ramsey, R. R. 121
Recent Indiana Weeds 214
Reclamation of Soil by Vegetation 259
Relation of Insects to Human Life and the Sciences 287
Relation of Size to Age in Freshwater Fishes 307
Revegetation of Soil 259
Rust Investigations, Methods 241
Scientific Education, Over-Standardization 47
Scott, Will 311
Seed Production of Allium vineale 213
Shirk, John C. 19
Silent Electric Discharge and its Effect on Gases 77
Smith, Ernest Rice 73
Spring Meeting, Minutes 11
Soil and Water Reactions in the Dunes Region 281
Soil Survey, The Development of 69
Standardization in Scientific Education 47
Stream Piracy near Greencastle, Indiana 73
Studies on Pollen, IV 265
Study of Locomotive Whistles 105
Study of the Productivity and Breeding Habits of the Bluegill, Lepomis pallidus 315
Termites of Indiana 299
Titration of Boric Acid 85
Tuberculosis in Indiana 55
Typhoid in Indiana 55
Van Hook, J. M. 233
Visher, Stephen Sargent 55

PAGE
Water, Peculiar Properties of 93
Weatherwax, Paul 223
Weed Survey of Indiana 216
Weeds of Indiana 214
Wheels, Power Required to Drive 115
Whistles, Locomotive 105
White County Plants 225
Winter Meeting, Minutes 23

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